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SCIENTIFIC AND INDUSTRIAL RESEARCH

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FOREST PRODUCTS RESEARCH 1956

Report of the Forest Products Research Board with the Report of the Director of Forest Products Research

LONDON
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1957

FOREST PRODUCTS RESEARCH BOARD
1956

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR 1956

We, the Forest Products Research Board, beg leave to present our report for the year ending 31st December, 1956.

We are pleased to record another very satisfactory year of steady progress in all the activities of the Laboratory. No major changes in the general direction of the work have taken place, and the proportions of effort given to basic and applied research are much the same as they were last year; there has, however, been a small increase in the amount of basic work and this we welcome.

The chief continuing projects which affect the whole Laboratory are still those of testing and evaluating new exotic timbers, mainly Colonial, and of investigating samples of home-grown species from the Forestry Commission's plantations with a view not only of assessing the quality of the timber from those which are now approaching maturity, but also of providing data which may assist the Commission in its future planting programme. With regard to the exotic timbers, some half a dozen species have been fully tested and reported upon, while in the project on home-grown species, ten consignments have been dealt with.

The new *Handbook of Hardwoods*, published during the year, has superseded the *Handbook of Empire Timbers*, and in it have been embodied the results of the tests carried out on hardwoods at the Laboratory since the last revision of the older handbook in 1945. A companion volume, the *Handbook of Softwoods*, is in the press. These two publications should be invaluable to timber merchants and consumers alike.

At the present time there is developing interest in the design and fabrication of structures in timber, both in its solid and in its laminated form, and there is an increasing number of architects, timber engineers and contractors who are concerned in timber construction. Thus there is a growing demand for data required in the efficient and economical design in timber and timber fastenings. The part being played by the Laboratory in the provision of such data and information is reflected in the reports and bulletins issued during the year. Among the projects under active investigation in this field are the grading of timbers for construction, the derivation of working stresses, problems in the jointing of wood, and research on the characteristics of full-scale structures.

We have to report that this year there has been a further sharp increase in the number of overseas visitors, who have come from over 40 countries. At the same time, the year's programme of home education and instruction has not suffered neglect, and has once more been very heavy, and the customary difficulty has again had to be met of apportioning the available time of the staff among the several types of visitors and students. All the visits are valuable for raising the standard of timber technology in industry, for the interchange of ideas on research, for the dissemination of the results of the work, or for the enhancement of the prestige of the Laboratory abroad, particularly in countries now developing. The perennial problem is that of striking a reasonable balance between these

diverse demands and of ensuring that, despite their importance, a minimum of disturbance is caused to the research work.

The year has also been a very active one for the senior officers of the various sections in their task of providing specialist advice to industry, both orally and in writing. In addition to general visits to make new contacts or to renew old ones, many special advisory visits on specific problems have served not only to take out to industry the Laboratory's knowledge but also to bring in from industry knowledge of current problems and fresh ideas. This year, also, officers have devoted much time to advisory work on committees, and as circumstances permitted, have given lectures to technical audiences in various parts of the country.

In his report, the Director deals in detail with the current projects in the various Sections of the Laboratory. Of these we select the following, recently completed or in progress, as being of special interest:

EXOTIC TIMBERS

The work on Meranti, Seraya and Allied Timbers has been completed, and is reported in *Bulletin No.* 36. Supplementary investigation of the *Parashorea* group, suggested by this work, is in hand, together with critical investigations on other exotic timbers. An article has also been published on African mahogany. This timber, mainly the product of three species of *Khaya*, shows considerable variation in quality as imported, and the results of many years' observations, summarized in the article, have made it possible to explain the causes of variation in this timber and to suggest means of improving the quality.

COMPRESSION WOOD AND TENSION WOOD

These abnormal types of wood, which occur naturally in the tree, are the frequent cause of distortion and machining difficulties in the timber. Two articles and a laboratory leaflet have been published to describe for industrial users the nature and significance of compression and tension wood.

SEASONING

The investigations on the general seasoning properties of various species and on the design of kilns have continued. In addition, further tests have been made on the effect of air speeds on drying rates, and a report has been published on the rate of evaporation from the surfaces of wet softwood.

STRUCTURAL USE OF TIMBER

Following the publication last year of the grading rules for home-grown softwoods, working stresses for design purposes for nine British and three commonly imported softwoods have been derived and published. A comprehensive investigation of imported structural softwoods is in hand.

In addition to the testing of several structures made outside the Laboratory, a portal frame arch has been constructed for tests to obtain data for the design of laminated structures of this type.

STRENGTH OF PLYWOOD

Average strength values have been determined and published for plywood of 38 species, which now include most of those likely to be of commercial value for the production of plywood. The project has, therefore, been concluded. A further Bulletin in the series on the strength properties of plywood deals with the influence of the adhesive on the strength of plywoods made from thin veneers.

WOODWORKING

For some years problems of rectilinear cutting have been studied by means of a low-speed apparatus, and more recently by a medium-speed prototype machine. A new machine has now been built, which will operate at speeds up to nearly 8000 feet per minute. Chip formation and cutting forces can now be observed from the lowest to the highest speeds.

Other current work includes study of planing to correlate the tangential force imposed upon the specimen with feed resistance, and a detailed investigation into the effect of the design and sharpening of the teeth on the performance of bow-saws.

PROPERTIES OF ADHESIVES

Two of the ten-year experiments on the durability of plywood glues have been completed and have been reported upon, and a summary of the results of all past and present durability tests has been issued. This summary will be brought up-to-date each year.

"SHELLY" GABOON

The investigation into the causes of "shelling" of gaboon veneers has been completed. It would appear that this defect is due to an inherent structural abnormality in the wood, but can be avoided by correct setting of the peeling lathe.

RADIO FREQUENCY HEATING

A report on the application of this type of heating to a batten-to-plywood joint has been issued—the first since the resumption of the work, which had been in abeyance for about five years. Further work on the manufacture of laminated beams using radio frequency setting is in progress. A report has also been issued on the ageing of glued joints set five years ago by radio frequency. The joints at the time of manufacture were slightly weaker than controls set at room temperature, but the difference has shown no tendency to increase during the period of ageing. The joints will be kept under observation for a further five years.

MYCOLOGICAL WORK

Further occurrences of the soft rot caused by *Chaetomium* have been recorded from widespread sources, and the laboratory investigations on the physiology of the fungus are continuing. A report has been prepared on the loss of strength of beech wood exposed to the attack of *Chaetomium*.

In addition to the long-term investigations, mycological projects in hand include work on the stimulation of *Coniophora* by sodium fluoride, the prevention of decay in boat planking by the addition of fungicides to the bilge water, and further experiments on the prevention of deterioration in logs.

ENTOMOLOGICAL WORK

The year's work has again been largely concerned with the long-term investigation of the life-histories, the biology and the control of the wood-destroying insects. Work is also continuing on the efficacy of gamma rays, high frequency currents and infra-red rays for the control of the timber-boring insects.

As part of the programme of the West African Timber Borer Research Unit, the full natural life-cycle of the oak Pinhole Borer has been worked out by an officer of the Unit stationed at the Laboratory. Further work on the biology of the insect is in progress.

WOOD CHEMISTRY

Further attention has been given to the structure and relationships of the hemicelluloses of wood, which constitute almost one-third of the total carbohydrate portion of wood. On partial hydrolysis they yield a complex mixture of acids—there are at least ten present in a beechwood hydrolysate—and on complete hydrolysis a mixture of sugars, the "building stones". Before the linkage of these sugars within the framework of the hemicellulose molecules can be determined, separation of the individual acids will be necessary. This work is now in hand.

HARDBOARDS FROM TROPICAL TIMBERS

The methods developed and previously reported upon for the successful manufacture of these hardboards involved a mild chemical treatment. A model Asplund Defibrator has now been installed and experimental work is in progress to study and compare the merits of the Defibrator process and of the semichemical method previously described.

ADVISORY SERVICE

During the year there has been little change in the volume and diversity of the requests for information. There has, however, been a significant and welcome fall in the number of mycological enquiries, due no doubt to the decreasing effect of the post-war attacks by dry rot.

MEMBERSHIP OF THE BOARD

We are glad to welcome Professor A. J. Sutton Pippard and Mr. L. B. Ercolani as new members of the Board, and Mr. W. A. Went as the Admiralty assessor, who succeeds Mr. O. T. Whitehead, who has retired.

January, 1957

R. G. BENNETT,
Chairman

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR 1956

Introduction

During the year there has been no significant change in the scope or the orientation of the Laboratory's work. There has again been a slight increase in the amount of basic research, and there is a slight fall in the demand made on some sections of the advisory service, but on the whole the proportions of effort expended on basic work, technical investigation and advisory services have not altered significantly. The testing of new exotic timbers and the investigation of home-grown species, the latter mostly from the plantations of the Forestry Commission, have steadily progressed, as have the other continuing projects of the various sections of the Laboratory.

General

STAFF, BUILDINGS AND EQUIPMENT

There has been a small increase in staff, the composition and proportions of which remain essentially unchanged.

No major additions or alterations to the Laboratory's buildings or equipment have been made during the year.

TOURS ABROAD

In January the Officer-in-Charge, Mycology Section, attended a meeting in Paris of a committee set up by the VIIIth International Botanical Congress to consider the standardization of tests of substances for the preservation of materials. After the meeting he took the opportunity of visiting institutions concerned with mycological research in wood.

The Officer-in-Charge, Chemistry Section, visited the United States and Canada in September and October, principally in order to attend conferences at Atlantic City, New Jersey, and Appleton, Wisconsin, on the chemistry and biochemistry of lignin. The opportunity was also taken to visit research institutions and industrial plants and to discuss developments in wood chemistry and wood utilization with workers in those fields.

An officer of Entomology Section attended the 10th International Congress of Entomology in Montreal in August, and subsequently paid a series of visits to laboratories and other institutions in Canada and the eastern United States to obtain information on current investigations on wood-boring insects and their control. It is gratifying to record that a special extension of the visit to include laboratories in British Columbia was sponsored and paid for by the Congress. The officer presented a paper dealing with investigations at the Laboratory on the eradication of wood-boring insects by gamma radiation.

A visit by an officer of the West African Timber Borer Research Unit, who is stationed at the Laboratory, was made to the Centre Technique Forestier Tropical and the Institut National du Bois in Paris to discuss work on ambrosia fungi and to observe the technical methods used by other workers in this field.

LIAISON AND COLLABORATION

Collaboration with other laboratories and with professional institutions is still expanding, and covers a wide range of subjects. During the year joint projects have included work on the preservation of marine timbers (Institution of Civil Engineers), of sleepers (British Railways) and of transmission poles (British Electrical and Allied Industries Research Association, Electricity Area Boards and the G.P.O.); on cooling towers (Central Electricity Authority), the metabolic products of wood-rotting fungi (London School of Hygiene and Tropical Medicine), the biology of timber-boring insects (Colonial Office, Forest Departments, and Research institutions) and the infestation of logs (West African Timber Borer Research Unit); on the structure of the hemicelluloses (University of Edinburgh), the production of hardboards from tropical timbers (Colonial Products Council) and the treatment of insect infestation by irradiation (Atomic Energy Research Establishment, Harwell). The durability tests on plywood for marine craft continue at H.M.S. Hornet.

During the year the two informal industrial advisory panels on plywood research—the Adhesive Makers' Panel and the Plywood Research Panel—have met as usual to discuss the Composite Wood research programme. Thanks are again due to the Associations and to the individual members of the Panels for their unstinted and valuable assistance.

Close liaison has been maintained with industry, particularly by the individual sections, whose discussions of topics and problems of common interest bring great mutual benefit. Members of the staff continue to serve on various technical and advisory committees.

ADVISORY SERVICE

In addition to the general dissemination of the results of the Laboratory's work, much staff time is devoted to dealing with the specific problems which come through visitors and visits, mail and telephone. Most of the industrial enquiries demand treatment by the relevant specialist sections, but there are as well many requests for information, largely by the general public, and most of these can be answered by the standard leaflets issued by the Laboratory. To take as a measure the enquiries answered by letter during the year the number was 5060. The number of standard information leaflets issued to the public directly or at exhibitions was 28,819.

PUBLICATIONS AND RECORDS

New Stationery Office publications issued during the year comprise the Annual Report for 1955, *A Handbook of Hardwoods*, three Bulletins, one Special Report and two Leaflets. *A Handbook of Hardwoods* contains up-to-date information on the properties and uses of over 200 timbers, including many that are comparatively new to the United Kingdom market, with descriptions of the trees and their natural distribution. *Bulletin No.* 36 "Meranti, Seraya and Allied Timbers" is a work of reference designed to elucidate the classification and nomenclature of the light and medium-weight timbers produced in South-East Asia by species of *Shorea*, *Parashorea*, *Pentacme* and *Anisoptera:* a brief description of the botanical composition and economic importance of the timbers in each of the countries is included. Grading rules for home-grown softwoods have already been formulated and *Bulletin No.* 37 "Working Stresses for Structural Softwoods" shows how working stresses for the two structural grades in the rules can be derived from the results of tests on small clear specimens; permissible

working stresses are given for various strength properties, for twelve common softwoods. *Bulletin No.* 38 summarizes the progress reports so far issued on a number of long-term experiments which aim at determining the suitability of the various types of adhesives for wood for use in a wide range of environments. "The Blunting of Wood-cutting Edges" (*Special Report No.* 11) describes the changes that take place in the condition and behaviour of high-quality edges formed in high-speed steel and hard-metal when they are used in association with different sharpness angles and cutting angles. The report also compares high-speed steel cutters with tools tipped with different classes of hard-metal as regards their ability to deal with plywood and normal and siliceous wood.

Leaflet No. 50 Defects Caused by Ambrosia (Pinhole Borer) Beetles supersedes No. 17. Leaflet No. 51 *Reaction Wood* (*Tension Wood and Compression Wood*) describes the two kinds of reaction wood, their origin and how they adversely affect certain properties of the timber in which they occur. Seven other Leaflets were revised. These and the papers published in journals are given in Appendix II. In addition 26 reports, including 18 on the subject of plywood, were prepared for limited circulation. It is of interest to note that *Bulletin No.* 31 on the decay of timber in boats has been translated into Icelandic and published in Iceland.

Programme of Research

WOOD STRUCTURE

COLLECTION OF TIMBER SPECIMENS

Nearly seven hundred specimens have been added to the Laboratory's reference collection during the year and approximately twice that number distributed, many of them to institutions abroad under exchange arrangements. Acquisitions included a number of small to medium-sized collections as follows:

tropical American timbers from Yale School of Forestry and the Forest Products Laboratory, Madison;

Hawaian timbers from Yale School of Forestry;

Philippine timbers from the Insular Lumber Company, Philadelphia;

Surinam and Indonesian timbers from the Landbouwhogeschool, Wageningen;

tropical African timbers from the Centre Technique Forestier Tropical, Nogent-sur-Marne;

timbers of Portugal and Portuguese overseas territories from the Laboratorio Nacional de Engenharia Civil, Lisbon, and the Laboratorio de Histologia e Tecnologia de Madeiras, Lisbon;

and local timbers from the Forest Departments of Ceylon, the Gold Coast, North Borneo, and Sao Paulo (Brazil) and the Division of Forest Products, Commonwealth Scientific and Industrial Research Organization, Australia.

As usual, representative specimens of consignments of timber brought into the Laboratory for test have been retained for permanent reference and numerous samples of commercial timbers have been received through trade channels. Grateful acknowledgement is made to all concerned for their co-operation.

MICROSCOPE KEY TO HARDWOODS

A start has been made in revising the microscope key to the identification of hardwoods, which uses perforated index cards, and which has been current since 1938. It is intended to publish this key as soon as the present revision is completed. Since it was originally compiled many timbers have been added and much

has been learned about the diagnostic value of anatomical features. The features for use in the key have now been critically reviewed and redefined in the light of present-day knowledge and a series of photomicrographs prepared. A systematic examination of representative specimens and of the relevant literature has been proceeding during the year. So far fourteen botanical families have been covered.

VARIATION IN THE QUALITY OF AFRICAN MAHOGANY

The mahogany imported in large quantities from the West Coast of Africa is mainly the product of three species, *Khaya ivorensis*, *K. anthotheca* and *K. grandifoliola*. They cover a wide range of territory and the climate and conditions of growth vary accordingly. It is not surprising, therefore, that the timber is rather variable in quality.

Studies of African mahogany extending over many years have reached a stage where it is possible to indicate the characteristics of the different species and the factors affecting the quality of the timber. The results of these investigations have been summarized for publication in the form of an article[1] explaining the causes of variation and suggesting ways and means of improving the quality of the timber, namely by marketing the species separately, by recognizing the importance of locality and by more careful attention to natural defects, including brittleheart and tension wood.

MERANTI, SERAYA AND ALLIED TIMBERS

The work of summarizing information on this group of timbers, culminating in the production of *Forest Products Research Bulletin No.* 36, has revealed certain gaps in our knowledge, and a supplementary investigation of *Parashorea* timbers has been started. In addition to the important commercial timber, white seraya (*Parashorea plicata*), the genus includes about a dozen species of which very little is known. Timber specimens of some of these, received recently from North Borneo, have been examined and further material is being obtained from Sarawak.

The investigation of the exceptionally wide variation in the density of *Shorea albida*, referred to in last year's Report (p. 10), has been completed and a report has been prepared for publication[2]. This investigation provides an example of co-operative research between the Laboratory and an overseas forest department. The Laboratory was interested in elucidating this problem and when the Sarawak Forest Department offered to provide a series of timber specimens collected in the course of an ecological survey, they were gratefully accepted. As a result of the Laboratory's investigations a tentative explanation of the exceptionally wide range of variation in density has been put forward. This has been made possible only because of the excellent field notes accompanying the timber specimens.

REVISION OF *PIPTADENIA*

A comparative examination of *Piptadeniastrum africanum*, formerly known as *Piptadenia africana*, and *Newtonia buchananii*, formerly *Piptadenia buchananii*, undertaken as part of the Laboratory's programme of timber investigations, revealed significant differences in the anatomical structure of these two species. While this investigation was proceeding Brenan[3] published his revision of *Piptadenia*, splitting it into eight genera. Accordingly the laboratory examination of the timbers has been extended to other related species. The material so far investigated, representing seven of the new genera, indicates that the classification based on anatomical structure agrees fairly well with that proposed by Brenan on morphological grounds. In order to make the investigation as complete as possible further material is being obtained from correspondents abroad.

COMPRESSION WOOD AND TENSION WOOD

Although the related phenomena compression wood and tension wood (together known as reaction wood) have long been familiar to timber technologists, many timber users have either never heard of them or do not appreciate their significance. Cases of abnormal distortion or splitting and difficulties in machining or finishing that have been referred to the Laboratory for explanation have frequently proved to be due to tension wood or, less frequently, to compression wood.

As a sequel to the article on tension wood in hardwoods, published in September 1955, a second article[4] on compression wood in softwoods has been prepared for publication. The substance of the two articles has been embodied in a leaflet[5].

TESTS FOR HEARTWOOD

To meet the requirements of specifications and for other reasons it is often necessary to determine the limits of sapwood and heartwood and there is a demand, particularly in industry, for a simple practical test such as a colour reaction. One such test that is commonly used for oak in the furniture trade is the Dimethyl Yellow reaction; a few drops of the reagent brushed on the dressed surface of the wood normally give a red colour with heartwood and a yellow shade with sapwood, the coloration depending on the relative acidity or pH of the wood. Representative samples of different kinds of oak have recently been examined to assess the reliability of this type of test. The results show that Dimethyl Yellow, as also the similar Methyl Orange, is normally satisfactory for distinguishing sapwood and heartwood of commercial European and American oak but is quite unreliable for Japanese oak. The reason is that in European and American oak the heartwood is distinctly more acid than the sapwood whereas in Japanese oak heartwood and sapwood are similar in this respect and give practically the same colour reaction.

The effect of fungal attack on the reliability of the Benzidine test for distinguishing sapwood from heartwood in pine timber has been investigated. This bears on the common problem of deciding whether samples of decayed wood submitted to the Laboratory for an opinion on the cause of the rot are sapwood (and therefore naturally susceptible to fungal attack) or heartwood (which normally means that the wood has been exposed to more severe conditions). When a few drops of a mixture of benzidine (in hydrochloric acid) and sodium nitrite are brushed on a clean surface of the timber, heartwood quickly develops a bright red colour while sapwood stains a yellow or yellowish brown shade. The reaction depends on the presence in the heartwood of pinosylvin and allied substances which react with the diazotised benzidine to give the red colour. The results of tests on samples of Scots pine exposed to the attack of various fungi indicate that in general the earlier stages of attack do not seriously affect the test but the characteristic red colour may fail to develop in heartwood that is in an advanced stage of decay. A full report of this investigation is in preparation.

RATE OF GROWTH AND QUALITY IN HOME-GROWN SOFTWOODS

Under normal forest conditions the annual growth rings generally tend to become progressively narrower with age, and the fact that the later-formed, narrow-ringed wood is usually heavier than the wood of the central core has led to the assumption that ring-width and density are causally related. The results of tests carried out in South Africa on rapidly grown timber of exotic pines have

indicated that this assumption is incorrect and have shown that the density of the timber depends on the age of the rings and is independent of their width. To discover whether these conclusions apply to softwoods grown in this country, material of varying ring-width has been selected from consignments coming into the Laboratory for test and supplementary material of Corsican pine, Scots pine and Douglas fir has been obtained from other sources. Observations on density, ring-width and anatomical structure are in hand. The results obtained so far suggest that the density/ring-width relationship is substantially affected by the age of the tree, and indicate that wide-ringed wood formed in middle life is likely to be denser than wood of similar ring-width produced in earlier years.

GROWTH STUDIES: LIGNIFICATION

The results of the work on lignification were communicated to the Linnean Society of London in April in the course of a symposium on the Laboratory's biological work. Common problems were discussed with members of the staff of the Low Temperature Research Station at Cambridge in May and the subject was discussed again at the Congress of the International Union of Forest Research Organizations at Oxford in July.

A small plantation of ash, sycamore, European larch and Scots pine has been established in the grounds of the Laboratory to provide material for physiological work.

ADVISORY WORK IN WOOD STRUCTURE

As usual many samples of timber have been submitted for identification (over twelve hundred in the course of the year) or for advice on their quality or suitability for various purposes. A common type of enquiry has to do with deliveries that are not up to expectation. Examination of samples from shipments that are unusually varied in character has sometimes shown that two or more species have been included. It is interesting to speculate how many cases of this kind pass undetected and to what extent this affects the reputation of the timber.

Streaks and discolorations thought to be due to incipient decay or contamination have proved to be natural deposits of gum or resin or heartwood coloration. In other cases the cause of distortion or splitting has been diagnosed as a growth defect such as tension wood or irregular grain rather than faulty seasoning.

Wooden articles that have failed in service have been examined to determine whether the fault was in the wood itself or was due to other causes.

Judging by enquiries addressed to the Laboratory there is a healthy interest in new timbers and in new sources of supply. Importers have asked for information about unfamiliar timbers offered to them by overseas shippers and several enquiries have been received from abroad about the commercial possibilities of hitherto undeveloped timber resources. Comparatively unfamiliar timbers that have been the subject of enquiry include:

mutenye (*Guibourtia arnoldiana*) from the Belgian Congo, a decorative hardwood resembling walnut;
Andaman bow-wood or chai (*Sageraea elliptica*);
mfunda (*Cynometra webberi*) of East Africa, of possible interest for flooring;
thingan (*Hopea odorata*) of South-east Asia;
mangrove (*Rhizophora* spp.);
ocote pine (*Pinus oocarpa*) of the mountains of Central America, a timber similar in character to American pitch pine;
Japanese varieties of pine and spruce.

Samples taken from trial consignments of "Chinese pine" shipped from Shanghai included a soft pine of the *Pinus strobus* type, larch, spruce and silver fir, as well as several species of hardwood.

A sample of "Chinese oak" from the same source proved to be a species of *Castanopsis*.

A South American country has sought advice on the possibility of using a local timber in place of imported supplies.

The number of external enquiries involving a written reply amounted to 503.

SEASONING

KILNS AND KILN SEASONING

Tests of the seasoning properties of numerous species have continued during the year and the large kilns have been used for drying loads of Japanese oak, white bombway, French beech and ramin. In the series of tests on the seasoning properties of home-grown softwoods, loads of Scots pine, western hemlock, Corsican pine and Douglas fir have been dried.

One load of Scots pine was dried at temperatures up to 210°F and a further load from the same consignment at up to 120°F. The time taken to dry the second load was approximately twice that of the first but the darkening in colour and the exudation of the resin from resin ducts and knots were very much less pronounced, and in fact were hardly detectable.

The smaller kilns were used for drying experimental loads of a number of species, including such woods as light red, yellow and white seraya, pillarwood, keruing, roble, Maracaibo boxwood, afrormosia and ramin. The home-grown roble proved to be very refractory in seasoning and its shrinkage was unduly large. Pillarwood likewise proved to be a very slow-drying wood and very prone to distort. Keruing also dried slowly but its final condition was comparatively good. Attempts to accelerate the drying of ramin by increased temperatures or lowered humidities were successful but only at the expense of excessive splitting.

One further load of $1\frac{1}{4}$-in. home-grown beech was dried in board form and a matched load in the form of $1\frac{1}{4} \times 1\frac{7}{8}$-in. curved sawn material for back feet of chairs. The conclusion arrived at as a result of these tests, which were carried out in co-operation with a firm of furniture makers, was that the drying of back feet as such is a more economic proposition than the drying of boards. It seems probable, however, that it may not always be the more convenient procedure. An article has been published on the results obtained in these experiments[6].

KILN DRYING IMPORTED REDWOOD

Redwood kiln dried in Scandinvaia for export to this country is seldom subjected to a drying temperature higher than 50°C (122°F), the reasons given for this being that at higher temperatures the wood darkens in colour, the resins exude on to the surfaces of boards and the knots loosen. This accords with the results of the tests on home-grown Scots pine noted above.

As there seems to be little doubt that the colour and surface appearance of this softwood have an effect upon the commercial valuation, the Laboratory has decided to issue two drying schedules for this species, one a relatively high temperature schedule for rapid drying and the other a low temperature one designed to preserve the natural colour and appearance of the converted material.

In order to obtain seasoning data on this species that would assist materially in the development of these schedules, a series of test runs has been undertaken

in an intermediate size kiln on matched loads of 2-in. imported Swedish redwood. The first load of this timber, which initially was at a moisture content of 20 per cent, was dried to 12 per cent in four days at temperatures ranging from 125° to 170°F, the second in seven days at 120°F throughout and the third in five days at 135°F throughout. As regards distortion, splitting, and the condition of knots, there was little to choose between the dried loads, but the general appearance of the first was considerably marred by exudation of resin and darkening of the surfaces. These effects were entirely absent in the second run and occurred only to a slight extent in the third. Their importance in practice is difficult to assess, the more so because the timber after planing was scarcely distinguishable from air-dried, but it seems probable that if the timber were to be resold it might be necessary to preserve its original appearance as far as possible. The tests confirmed that to do this the temperatures employed in kiln drying should not exceed about 130°F.

TESTS ON THE EFFECT OF AIR SPEED ON DRYING RATE

During the past year three series of runs have been carried out in the special kiln used for these tests and improvements to the kiln have been made.

Two matched loads of 1-in. beech were dried, one piled with ½-in. sticks and one with 1-in. sticks. The fan speed was adjusted so that the volume of air passing through the gaps was the same in both runs and the humidity controlled to produce similar drying rates of the inlet samples. The fact that there was no significant difference in the times taken to dry the whole loads indicated that the volume, as well as the speed of the air passing through the air gaps, is of importance.

A second series of runs demonstrated that the effect of increasing the air speed from 4 ft/s to 8 ft/s without any modification to a standard schedule may be to reduce the drying time by about 35 per cent. The splitting hazard, however, would be increased. In a further run at the higher air speed the humidity was raised sufficiently to keep the inlet samples drying at the presumed maximum safe rate and the reduction in time was then only about 15 per cent.

The third series was conducted to study the effect of air speed on drying when the circulation is reversed at ¼-hour intervals and the drying rate of both sides is kept, by lowering the humidities, to that of the air-inlet side of a run with unidirectional air circulation at normal schedule. Indications were that the effect of air speed was much less pronounced than with one-way-circulation drying but some aspects of the results obtained in this series have made it desirable to verify them.

EVAPORATION TESTS

A series of tests has been carried out to determine the effect of air speed upon the rate of evaporation of moisture from the surfaces of wet softwood. The values of the coefficient of heat transfer from air at 60°C (140°F) to water at 50°C (122°F) for mean air speeds ranging from 1½ to 9 ft/s have been estimated from the rate of moisture loss from wet Corsican pine during the period of constant drying rate. It was established that the relationship between the heat transfer coefficient and the mean air speed was approximately linear and could be expressed by the equation:

$$h = 1{\cdot}9 + 0{\cdot}48V$$

where h is in B.t.u./ft² h °F and V is in ft/s.

A report[7] on these findings has been published and a second report[8] issued

in which, from the data already obtained, calculations are made relating to the drop in temperature across a pile of wet timber, and to the effects that reversal of direction of air flow can have on the overall rate of drying.

In the course of the investigation it was necessary over a wide range of air speeds to determine the ratio V_{mean}/V_{max}, where V_{mean} is the average velocity and V_{max} the maximum velocity of air moving between layers of wood separated by 1-in. sticks.

Air speed tests made with the aid of artificial smoke demonstrated the "drag" effect of the wood surfaces on the air flow, and photographs illustrating this effect at a speed of 2 ft/s are reproduced in Plate 1.

DISTORTION EXPERIMENTS

A report[9] has been prepared and circulated on the first series of tests designed to study the effect on the subsequent distortion of timber samples of subjecting them to mechanical restraint during the drying process. A repeat series of tests on samples of African mahogany is now in progress.

MOISTURE CONTENT TESTING OF IMPORTED SOFTWOOD

As a result of complaints from importers of Scandinavian softwood that there has been a tendency for such material to distort and develop blue stain, moisture content determination tests have been made on some twenty consignments of redwood from different sources. The bulk of the material tested was found to average between 18 and 22 per cent and was reasonably uniform across the section. Such results do not confirm the view that moisture from comparatively wet centres of planks finds its way out slowly when the timber is in store in this country, thus leading to development of blue stain.

MISCELLANEOUS TESTS

In response to requests from industry, special investigations have been carried out on the kiln drying of hardboard after impregnation with water-soluble salts and on the kiln drying of maple squares imported for the manufacture of billiard cues.

WOOD BENDING

Solid Bending

The routine testing of timbers to determine their steam-bending properties has been continued and data on some nine different species have been obtained. Included among these are muhuhu, light red seraya, greenheart, Tasmanian myrtle and European plane. The myrtle was found to be suitable for many purposes for which solid bends are normally required and the European plane proved to have bending properties similar to such well known bending species as ash or beech.

In co-operation with a firm of furniture manufactuers, an improved technique has been developed for producing serpentine shapes of moulded cross-section from beech. The moulded lengths are first steamed for softening and then bent to shape between suitably shaped forms and finally set to shape in a period of about eight minutes by the use of radio frequency heating.

Laminated Bending

Basic data on the limiting radii of curvature of nine different hardwoods and one softwood have been determined.

An investigation into the magnitude of outward movement or "spring-back" of laminated bends that occurs on releasing them from the bending forms has

been completed and a report on the findings is in preparation. Formulae for estimating the extent of this movement for any particular assembly have been evolved.

A new and comparatively simple technique for making laminated hoops has been developed in co-operation with a firm engaged in the manufacture of musical instruments. By this method, which consists essentially of pressing roughly assembled laminae between a split outer form and a centrally placed circular and flexible steel strip, hoops to form the rims of tambourines have been successfully mass-produced by the firm.

Plywood Bending

Work has been carried out to determine the bending properties of ceiba plywood and data relating to the influence of various factors on the setting to shape of African mahogany plywood have been obtained. It has been shown, for example, that the thinner the material, the greater is the final deviation of the bent part from the shape of the bending form. It appears also that material $\frac{3}{16}$ in. in thickness bent around a form heated to 350°F becomes set in about $2\frac{1}{2}$ minutes and that no advantage is to be gained by increasing this temperature further.

Miscellaneous work has included the making of sections for a stressed-skin plywood arch of 30-ft span designed for strength-testing investigations.

ADVISORY WORK ON SEASONING AND BENDING

In addition to the many visits received from kiln owners, manufacturers and others interested in seasoning and bending, some forty-five visits have been made to firms.

The number of enquiries dealt with in Seasoning and Bending has amounted to 784.

TIMBER MECHANICS

TESTING OF TIMBER FOR THE COMPARISON OF SPECIES

During the year further work has been carried out on this continuing project. A number of home-grown softwoods have been tested in the green condition. The species examined include five consignments of Sitka spruce, two of Scots pine and one each of western hemlock, Japanese larch and Leyland cypress. Work is in progress on three consignments of Douglas fir.

Tests have also been begun on some Colonial hardwoods. Kapur and two species of light red seraya from British North Borneo, and pillarwood from Kenya have all been tested in the green condition. Consignments of white seraya and yellow seraya are also under investigation.

PROPERTIES OF ENGLISH ASH

The existing strength data on English ash have been obtained from tests on material taken from trees of considerably larger diameters than those now being used for sports goods manufacture. There appears to be some doubt as to whether these data are truly representative of the species as grown in the United Kingdom, and as strength data for ash are used as a basis for comparison of timber having tough characteristics it is desirable to confirm or amend such existing data as may be necessary.

A special investigation to re-assess the strength properties of ash on material of age and quality similar to that being used at present has been put in hand, and is planned to include studies of the relationships between the strength data and

other properties such as density, rate of growth and wood bending. The possibility of a torsion test as a measure of toughness and the influences of the various stages in the steam-bending process on the strength properties, with special reference to the abnormally high percentage of failures in hockey sticks in play, are to be explored.

The investigation will be spread over a period of three to four years, ash being sampled as widely as possible from areas where it is being felled for sports goods manufacture.

STRUCTURAL USE OF TIMBER

The investigation of home-grown softwoods in structural sizes has continued. Grading and testing of consignments of Scots pine from the New Forest and Strathspey and western hemlock from Novar Estate, supplied by the Forestry Commission, have been completed.

The Scots pine from Strathspey was about ten per cent stronger in structural sizes than the same species from the New Forest, even though the latter material was of higher average density and had higher strength properties when tested in the form of small clear specimens. The difference in strength in the structural sizes was due to the relatively large knots present in the New Forest material.

The western hemlock was slightly less strong and about ten per cent less stiff than hemlock from Dunster previously tested, mainly on account of a density difference.

As stated in the Report for 1955 (p. 16) the publication of recommended grading rules for home-grown softwoods makes necessary the provision of working stresses for the various grades and species of timber likely to be used for structural purposes. The results of strength tests on small clear specimens of timber, whilst enabling comparisons between species, cannot be used directly as safe working stresses necessary in structural design; they can, however, be used for the derivation of suitable working stresses for the two structural grades in the grading rules. The natural variability in the strength of timber is taken into account and a safety factor used to ensure that under normal conditions of use the stress imposed on a structural member will not exceed its limit of proportionality in bending. Permissible working stresses are derived for all the strength properties likely to be required in design for nine of the most widely grown British Softwoods and three of the more commonly used imported ones. These working stresses have been published[10].

A new project has been started to obtain reliable strength data for the most commonly used imported structural softwoods. The species to be investigated are Baltic redwood, Baltic whitewood, western hemlock and Douglas fir. The project has been designed to provide information on the variations in strength to be expected over the full areas of production of each species. Thus, with Baltic redwood, provision has been made to provide up to forty-five consignments taken from current shipments from various areas in Sweden, Finland, Russia, Siberia, the Baltic States and Poland. Tests have already been completed on seventeen of these consignments. In addition, consignments of western hemlock and Baltic whitewood have been tested. All the tests are being made in accordance with the standard procedure for the testing of small clear specimens.

STRENGTH OF TIMBER STRUCTURES

The interest in the use of timber for medium and large-scale structures has been steadily increasing in recent years and many strength tests of prototype structural units have been carried out in the timber structures testing laboratory. This

laboratory has been described in a recent article in the technical press[11] and is shown in Plate 2.

The units tested as prototypes during the past year comprised one 40-ft span timber frame, a 30-ft laminated inclined portal arch, six framed trusses of spans ranging from 20 to 30 ft with nailed and bolted joints, and one glued Assembly Hall truss of nearly 45-ft span. In addition, four box beams, two with spans of 24 ft and two of 26 ft, and six lattice beams with webs of diagonal boarding and spans of from 12 ft 8 in. to 44 ft 4 in. were tested. In most of these the "cable-pulley" system developed at the Laboratory for applying the load was used. This system has proved most efficient in operation and it has been adopted by various authorities interested in the testing of timber structures, both at home and abroad. Additional point loads were applied in some of the tests by means of hydraulic jacks. Plate 3 shows the laminated portal arch under test.

STRENGTH OF NAILED JOINTS

The report of the investigation to study the effects of the drilling and clenching on the strength of nailed joints mentioned in the last Report (p. 16) has now been published[12].

Supplementary tests on nailed joints have indicated that both the stiffness, as indicated by the load to cause small slips, and the ultimate strength of joints, are unaffected by the direction of loading with respect to the grain of the member. The relationship between joint strength and stiffness and the moisture content of the joint members has also been investigated. Joints with members at 12 per cent moisture content were stronger than joints at 18 per cent moisture content and very appreciably stronger than joints with members in the green condition. The loads to cause small slips of the order of 0·030 in. also increased as the joint member decreased in moisture content.

The results of all the various investigations on nailed joints have been analysed and suitable permissible loads for nails loaded laterally in single or double shear have been derived.

STRENGTH OF GLUED JOINTS

The investigation of the strength of glued joints has continued. Further exploratory tests have been made of glued joints of structural size to examine the effect of some variable factors on their strength and to study the behaviour of the joints under load. Glued joints tested in compression failed at much higher loads than those tested in tension. Examination of the joints under test and of their failures suggests that the higher strengths in compression may be ascribed to a direct transference of load from one member to another owing to distortion. Some tests to examine the effect of the free length of the outer members of a three-member double-shear glue joint on its strength have also been made. When joints are loaded in compression the free length determines the amount of bending occurring in them, which in turn affects the magnitude of the secondary stresses acting perpendicular to the glue film at the latter's boundary. The results of these tests indicate a marked reduction in the shear strength of the joint with increase in the free length from 1 in. to 12 in.

STRENGTH OF PLYWOOD

General

The testing of samples of $\frac{3}{16}$-in. 3-ply has continued and average strength values have now been determined for a total of thirty-eight different species of wood. An article has been published[13] which gives the strength data for the

thirteen species not included in previous reports. It is believed that most species likely to be of commercial value for the production of plywood have now been tested and work under this project is therefore being concluded.

Effect of Adhesive on Strength

A report on the results of an investigation to determine the influence of the adhesive on the strength properties of plywood has been prepared for publication[14].

Strength tests on samples of gaboon plywood containing veneers ranging in thickness from $\frac{1}{10}$ to $\frac{1}{50}$ in. have shown that the general equations derived for calculating the strength of structural plywoods can be applied with reasonable accuracy to constructions having veneers not less than $\frac{1}{20}$ in. thick. For plywoods made from thinner veneers, however, considerable error can result because of the increasing contribution of the adhesive to the total strength of the plywood. The presence of the adhesive influences the structure of plywood, and consequently its strength properties, in two ways, firstly by compression of the wood fibres adjacent to the glue lines and secondly by impregnation of the fibre cavities. The compression which results from a plasticity of the wood brought about by the presence of the adhesive varied with different adhesives and was about three times as great with a phenolic resin as with a urea resin. By extending the general equations to include the layers of impregnated wood, that is by treating plywood as a composition of layers of wood separated by layers of a compressed impregnated wood, accurate assessments of bending, compression and tension strengths can be made for plywoods made from veneers less than $\frac{1}{20}$ in. thick. These assessments, however, require considerably more basic data than are needed for the general equations and since such extra data will not normally be readily available no alteration to the procedures derived for calculating the strength of structural types of plywood is suggested.

The presence of the adhesive in plywood was found to affect its hygroscopic properties. Moisture contents as indicated by the oven-drying method increased as the veneer thickness was reduced, the increase being greater with phenolic resin than with urea resin. Moisture determinations would suggest that loss of volatiles from the adhesive could not account for the increase and that some change in hygroscopicity must take place. It may therefore be inferred that because of these changes the strength/moisture relationships accepted for solid wood are not applicable to plywood.

Variability of Plywood

Strength tests on a number of samples of commercial gaboon plywood have been completed and average values together with variation statistics for bending, compression and tension strengths have been determined. A comparison of the variabilities of laboratory and commercially produced plywoods is being made as a first step in the derivation of working stresses for plywood.

LAMINATED TIMBER CONSTRUCTION

Laminated Arch Design

A laminated timber arch, of the inclined portal type (Plate 3) with a span of 30 ft and an apex height of 16 ft and tapered in depth has been made at the Laboratory. The timber used was good quality Douglas fir and the knee of the arch, which had a radius of about 7 ft, comprised 13 laminations, ten of which were $\frac{3}{4}$ in. thick and three $\frac{1}{2}$ in. The laminations were bonded with a casein glue.

The arch will be subjected to a series of tests to obtain data for design purposes.

For the first series of tests the arch has been erected as a three-pinned member. Various loads will be applied and the strains and deflections measured in order to assess the applicability of current arch design methods to a laminated timber member.

Effect of Curvature on Strength

In fabricating a timber arch each lamination has to be bent initially to the required curvature before the adhesive is set. This initial bending induces stresses which may in part remain after fabrication is complete. The residual stresses influence the strength of the arch and in design the magnitude of the influence must be known. Data on this are available for Douglas fir and southern pine but are entirely lacking for Baltic Redwood, a species extensively used for structural work in this country. An investigation to provide the required information has been begun.

EFFECT OF DEPTH ON THE STRENGTH PROPERTIES OF TIMBER BEAMS

The completion of the investigation into the effect of depth of section on the strength and elastic properties of timber beams has been followed by a more detailed investigation of the behaviour of timber when subjected to bending stresses. This has involved a study of the strain distribution across the depth of a beam.

Conventional grid type strain gauges were used to examine strain distribution. Beams 8 cm in depth, with gauges spaced at $\frac{1}{2}$ cm down one side at the centre of span, were adopted for the test. An additional gauge was fixed on each upper and lower face of the beam to obtain strain measurements in the extreme compression and tension fibres respectively. All the strain readings during test were made at constant beam deflection as distinct from constant load.

The results of these tests indicated that during the initial stages of loading the distribution of strain is approximately linear from the upper to the lower face of the beam. When the load is increased up to and beyond the proportional limit, the strain distribution remains essentially linear except in those fibres extending to about one-quarter of the depth from the extreme compression edge, where there is a slight increase in strain. On the tension side of the beam the strain distribution remains approximately linear but the strains developed are slightly less than the corresponding ones on the compression side.

It was found that the position of the neutral axis is by no means constant. It may be slightly above or below the centre of depth initially but loading up to proportional limit of the extreme compression fibres produces a slight downward movement by amounts varying up to two per cent of the depth of the beam. Further loading beyond this point causes a more pronounced movement of the neutral axis until at final failure under load the distance between its initial and final position, in all the beams tested, varied from five to nine per cent.

A series of supplementary experiments was made in order to compare the behaviour of wood when subjected to bending, compressive and tensile stresses. Tests were made in direct tension and compression on material taken from the ends of the 8-cm-deep beams.

The results of these tests show that the proportional limit in direct compression occurs when the stress is about 80 per cent of the ultimate value. When matched material is stressed in direct tension the stress-strain curves are essentially linear until ultimate failure occurs and there appears to be no well defined

proportional limit. The proportional limit stress for the beams from which the material was taken is about 70 per cent of the ultimate value.

The modulus of elasticity in direct tension was generally found to be slightly greater than that in direct compression, the difference being of the order of 5 to 10 per cent. The modulus of elasticity in static bending was about 10 to 20 per cent less than that in direct compression.

ABRASION

Standard abrasion tests have been completed on African padauk. This hardwood possesses high wearing qualities and its behaviour under test suggests that it is best suited for most conditions of pedestrian traffic. Tests have also been made on pillarwood from Kenya. The results of these have confirmed earlier assessment of the suitability of the species for flooring—its very high wearing qualities and its smooth wear under abrasive action. The expected resistance to wear of the Colonial timbers kapur, keruing, two species of light red seraya and yellow seraya has also been confirmed by tests.

Tests have also been carried out at the request of a chemical agency to examine the resistance to abrasive action of a special lacquer type of floor finish. These have indicated that the finish possesses a high resistance to wear and in this respect is superior to the normal oil-resin type of floor seal.

OTHER TESTS

The demand by industry for testing services continues and a number of *ad hoc* investigations have been carried out. Tests were made to determine the relative strength of various types of oar construction with a view to improved design and assessment of performance, to examine the effect of moisture content on certain strength properties of iroko used in telephone exchange equipment, and to determine the effect of incising prior to preservative treatment on the bending strength of redwood. The effect of a special high temperature drying technique on the strength of timber has also been investigated.

ADVISORY WORK IN TIMBER MECHANICS

Enquiries on the strength of timber, plywood, and laminated timber construction have totalled 300 during the year. A number of these concerned specifically the construction of laminated members, both curved and straight, and the design of box beams. Visits were also made to a number of firms engaged on laminated timber construction. Manufacturers' problems arising from the construction of gymnasium equipment have also been considered and the Laboratory has continued to advise on matters dealing with the structural use of timber, the testing of prototype structures and the utilization of hardwoods for flooring. Advice has also been given to two industrial concerns interested in establishing their own testing laboratories.

WOODWORKING

PLANING INVESTIGATIONS

The work on planing described in the Report for 1955 (p. 21) has now been divided into investigations of frictional resistance, chip formation and cutter forces, on an actual surface-planing machine, and researches into the theory of cutting, using specially constructed apparatus. This latter work will eventually be applicable to other woodworking processes, including sawing.

The investigations using the surface-planing machine were extended to correlate the average tangential force imposed on the specimen with the feed resistance under conditions almost free from friction. A special apparatus was constructed for carrying the wood test pieces past the rotating cutter-block free from contact with the metal table of the planer. It consisted of a travelling carriage mounted on ball-bearing rollers which run in channel tracks on the planer. This assembly was moved by means of a cable and drum, which was driven by an electric motor through a variable feed gear, worm reduction and clutch. A cantilever beam dynamometer was used as a link between the carriage and the cable for measuring the resistance to feeding, the deflection of the beam under load being recorded electrically. The input power to the motor driving the cutterblock was measured by a recording wattmeter and, with the aid of the efficiency curve for the motor, the net power required in planing could thus be determined. A series of tests was carried out on eight different species at a range of feed speeds from 20 to 60 ft/min, 30° cutting angle, and a spindle speed of 3600 rev/min. The results of these tests indicate that the average tangential force imposed on the wood, calculated from the net power demand, is in general of the order of 5 per cent less than the resistance to feeding.

Further studies are being made to examine the influence of the length of surface of separation on the average cutting force during each cutter engagement. The use of honed cutters, with subsequent jointing, will give an indication of the effects of the jointing operation on the average tangential force, and thus on the net power demand, when planing both softwoods and hardwoods.

The work on the theory of cutting has been concentrated on the problems of rectilinear cutting, in order to simplify the initial studies in a largely unexplored field. On the low-speed apparatus described in the Report for 1955 (p. 22) a further series of cutting tests has been carried out: depth of cut and cutting angle were varied, and the forces along and perpendicular to the cut surface were recorded. Fig. 1 shows the variation in force with depth of cut. Analysis of these results shows that no simple formula relates the forces to the other variables.

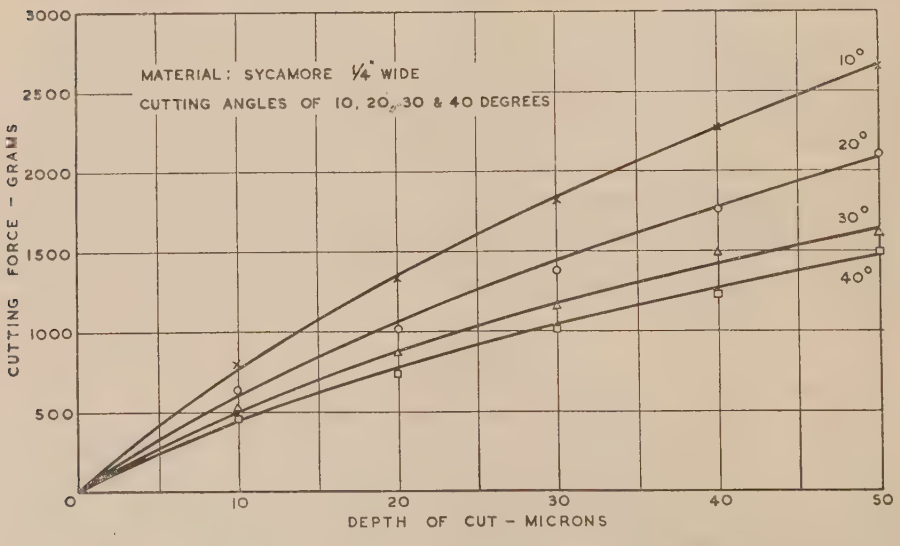


Fig. 1. Cutting force (parallel to direction of cut) and depth of cut

Work is to be continued to explore what happens in the wood adjacent to the cutting edge, with the hope of elucidating the mechanism of failure of the wood substance as it is parted from the parent material and formed into a chip.

A start has been made on investigating the possibilities of developing a technique for the preparation of sections through partly severed chips, for microscopic examination, and it has been possible to observe, under polarized light, compression failures in the cell walls ahead of the cutting edge (Plate 4).

The prototype high-speed rectilinear machine was used for a series of tests in which chip character and dimensions were studied while speed, cutter angle, and depth of cut were varied. Of particular interest was the phenomenon of "lobster-back" chips, in which the chip formed a long continuous shaving which failed in bending at regular intervals as it was deflected up the face of the cutter, so that its final form was a coil. The length of the "flats" between the bending failures can be shown theoretically to be related to the chip thickness by an equation of the form

$$A\sqrt{t}=\tan\left(\frac{B}{nt^{1.5}}\right)$$

where t is the thickness and n the number of "flats" per inch length

A and B are constants depending on the properties of the wood and other cutting conditions. Fig. 2 shows a series of experimental points, and a curve of this form fitted to them.

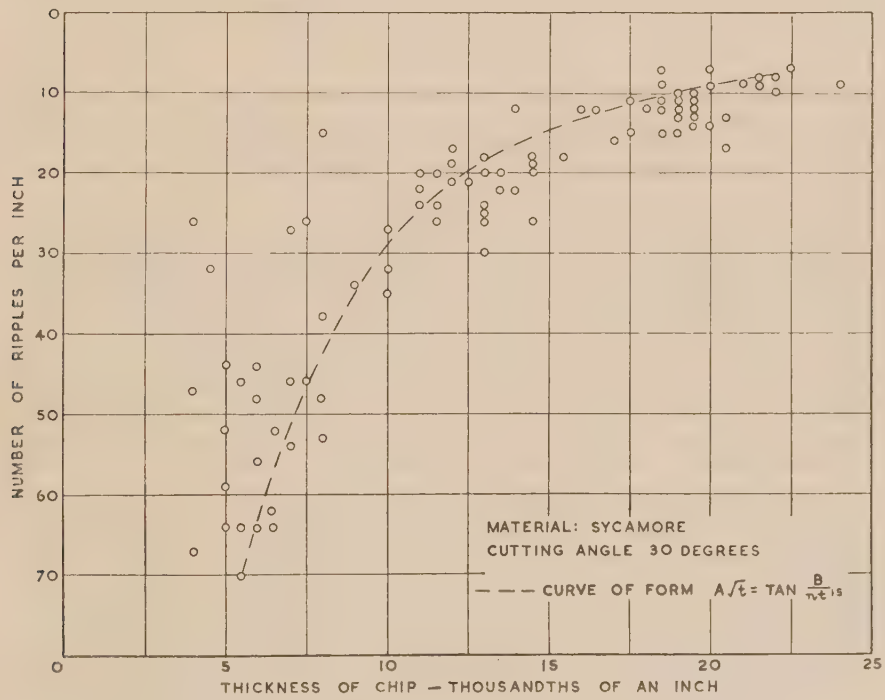


Fig. 2. Number of breakages per in. in chip against chip thickness

It has been claimed that the cutting speed has no effect on chip formation in such studies as these, but the results obtained on the prototype high-speed and the low-speed machines do not bear this out. In view of this, and because it was

not possible to measure the cutting-forces on the prototype machine (which was of very simple construction) a new machine has been designed and built which will allow the measurement of forces up to the highest speeds employed in woodworking. A device to give purely linear motion at such speeds would be impracticably large, so the machine has been designed to operate by the rotation of a large arm carrying the wood sample: the geometry of the layout is such that the departure from linearity is very small during the cutting cycle, and approaches nil at one instant, at which the observations are taken. The force-measuring devices are incorporated in the mounting of the cutter, which has a "single-shot" feed mechanism so that one cut only is taken per test cycle. Means are provided for varying the cutting angle and depth of cut. Plate 5 shows the machine with the safety-guards removed, and Plate 6 a close-up of the cutting head and wood sample.

Proving runs of the machine and its associated instrumentation have shown that it will operate satisfactorily at cutting speeds of from 700 to 7700 ft/min: higher speeds could be reached, if required, by streamlining the rotor.

On this machine a series of tests is now in progress covering the conditions previously investigated on the prototype machine, with a view to correlating the results obtained on the two machines.

The combination of this new machine and the slow-speed machine will make possible the observation of cutting forces and chip formation at all speeds from lowest to highest, under conditions of continuous cutting.

DOVETAILING

Following some simple preliminary tests, a programme of work has been planned to investigate the influence of variations in the angles and dimensions on the strength of machine-cut dovetails. The necessary special tools have been obtained, and the tests are being carried out as other work permits.

BOW SAWS

Service trials carried out on a number of bow saws have led to a detailed study of the effect that the design and sharpening of the teeth has on the performance of this class of saw. With a bow saw used as a hand tool in the normal manner, the speed of sawing and the forces exerted on the saw during cutting are likely to vary considerably from cut to cut and preliminary work was concerned with methods of estimating accurately the performance of the saws. A machine was constructed in which the saws could work under constant conditions similar to those found in practice. Experiments with this machine showed that only small changes occurred in the forces parallel to the line of the saw teeth with variation in their design and in the density of timber cut and that the main criterion of saw performance was the number of strokes required to cut a constant area of wood.

It was found that the quality of the sawn surfaces, the tendency for the saw to vibrate in the cut, the ease of cutting and the rate at which the teeth blunted were related to the design and spacing of the teeth, and that saws having relatively few teeth of good design gave the best performance. Special attention was given to saws having series of two cross-cut and one raker tooth. Experiments showed that the performance of such saws depended mainly on the ability of the cross-cut teeth to scribe deeply into the timber and that to obtain a satisfactory scribing action lance-like tooth points, as formed by wide bevels, were required. Small errors in the sharpening and setting of the cross-cut teeth had a marked effect on the performance of the saws and, where one range of teeth was consistently higher

than the other, caused the saws to deviate from their line of cut. A study of the cutting action of the two classes of teeth on these saws showed that the height of the raker teeth relative to the points of the cross-cut teeth depended on the penetration of the latter into the wood; tests indicated that a satisfactory filling of the raker gullets with sawdust was not obtained unless the height of the raker teeth was determined and maintained carefully. Attempts to improve performance, that is to increase the amount of timber cut by a saw before becoming blunt, by hardening of the teeth do not appear to be worthwhile without adequate care in tooth design.

STANDARD WOOD-WORKING TESTS

Full-scale standard tests have been carried out to determine the working and nailing properties of the following species.

Muhuhu, kiln dried, from Tanganyika
Caribbean pitch pine, air dried, from Nicaragua
Cupressocyparis leylandii, kiln dried, from the Forestry Commission, Wales
Two species of light red seraya, kiln dried, from North Borneo
Kapur, kiln dried, from North Borneo
Scots pine, kiln dried, from the Forestry Commission, Strathspey, Scotland
Scots pine, kiln dried, from the Forestry Commission, New Forest

The Scots pine from Strathspey was kiln dried under low and high temperature schedules and the standard tests on this consignment were extended to determine the effect of these schedules on the working qualities of the timber. There were indications that the high temperature treatment reduced the tendency of the timber to clog saw teeth but had no other effect on the working properties of the timber.

ADVISORY WORK IN WOODWORKING

Advice has been given to many branches of the woodworking industry on methods of improving efficiency in sawing and machining operations, the working properties and finishing of different timbers and on many other matters in sawmilling and woodworking. Visits were made to several sawmilling and woodworking firms to advise on methods of production. Numerous enquiries concerning the utilization of wood waste, the burning of wood and sawdust and the production of charcoal have been dealt with.

Technical enquiries amounted to 170 during the year and visitors requiring information numbered fifty.

COMPOSITE WOOD

PROPERTIES OF ADHESIVES

Two of the long-term experiments on the durability of glues have completed their ten years' period. In that known as Series II, the adhesives were tested in beech plywood three-sixteenths of an inch thick exposed to the weather in open fields, submerged in water, and stored in an open-sided shed and in a normally heated workshop. The report[15] gives the performance of all types of glues in these environments. In the outdoor exposure, only phenolic and resorcinol resins survived the full decade.

The second experiment[16] to reach completion is one concerned with cold-setting glues for assembly work, using the "Ply-clad frame" test unit first described in the Report for 1939–47 (p. 33). These units were softwood frames about 5 ft by 2 ft to which beech and Douglas fir plywood panels were attached by

various gluing processes. They formed the southern wall of a row of hutments built in an open field, and thus had full exposure to weather on one side of the unit whilst the other had the conditions in a ventilated unheated shed.

Table 1 shows the time in months for glues of various types to reach a defined amount of failure under the two conditions of exposure.

Table 1

Glue	Beech plywood		Douglas fir plywood	
	Weather side	Shielded side	Weather side	Shielded side
Animal	2	2	9	6
Casein	6	12	12	60
Urea resin	18	48	66	*

* Had not failed at ten years

Phenolic and resorcinol resins had given somewhat anomalous results in that partial failure had occurred in some of the units in an irregularly distributed manner. At the end of the experiment, when destructive examination of the units was permissible, an explanation of this was found. In the design of the experiment, two methods were used for holding the plywood to the frame during the assembly gluing. In the first, sufficient load was applied in pressing to ensure continuous contact. In the second method, nails acting through tacking strips were employed. It was believed that the nail-spacing used ensured that the glue line, even if thick, was continuous and without voids or air bubbles, and indeed, initial examination of the joints from the outside gave support to this by the appearance of the "squeeze". The final examination, however, showed that areas of discontinuity had formed in some of the glue lines, and that separation of the frame and plywood had occurred before the adhesive had set.

Analysis of the results showed that phenolic and resorcinol resins would have withstood full exposure to weather for the ten years with little or no deterioration, if the joint had been properly made in the first place. The troubles arose, not from thick glue lines as such, but where inadequate pressure had failed to force the liquid glue into continuous contact with the mating faces of the joint or where premature relaxation of pressure allowed the surfaces to separate and rupture the still unset glue line.

Other long-term durability experiments continue, and the most recent of these described in the Reports of 1954 (p. 19) and 1955 (p. 22) have had their first examination at 18 months.

For all such experiments, progress reports are issued at appropriate intervals. These papers are not only numerous but are prepared for detailed study rather than for speedy reference. The Laboratory has, therefore, issued a summary of results for all past and present experiments on the durability of glues. Entitled "The Efficiency of Adhesives for Wood", this summary will be revised each year, and circulated automatically to members of the Adhesive Makers' Panel and their associations and to any others on request. For wider circulation, the summary has also been published as a Bulletin (No. 38), which will be revised at intervals of three to five years.

Previous reports have mentioned work in progress on the gluing of veneer or solid timber that has been treated with preservatives against fungal and insect attack. Accumulating data show that the presence of these chemicals lowers the quality of the glued joint to a greater or lesser extent depending on the species of timber, the kind of preservative, and not only the type but also the brand of glue. It is, therefore, not possible at present to generalize, and the experiments are continuing.

Work has continued on methods of testing the thermo-plastic types of glues such as P.V.A. emulsions. *Bulletin* 20: *Requirements and Properties of Adhesives for Wood*, first issued in 1946, has been completely revised.

PROPERTIES OF PLYWOOD

Over a number of years, routine tests have been made on the movement, or shrinkage and swelling, of plywood under changing atmospheric conditions. Data for sixty-nine species have been collated[17]. The movement across the grain of a three-ply board is 1·5 times that along it, but expressed as the average of the two directions for the sixty-nine species, plywood initially in equilibrium with the conditions in a strongly centrally heated room expands by one-fifth of one per cent when moved to a damp unheated room and by one-quarter of one per cent when water-soaked.

For the same timbers, three-ply has an average movement one-twenty-fifth that of solid wood, both measured across the grain.

DISTORTION OF PLYWOOD

In the Reports for 1953 (p. 24) and 1954 (p. 22) an investigation was described which aimed at finding the causes of distortion in plywood. Panels five feet square, half an inch thick, were made from veneer specially selected for straightness of grain and absence of defects. Each set of five boards was arranged to contain one of a number of manufacturing variables which were thought to cause distortion. After pressing, the test material was subjected to three wetting and drying cycles and the distortion of each panel measured at points in each cycle. Previous work on three-ply panels, 2 ft by 1 ft, had indicated that consistent results were obtained only after three identical cycles. With the 5 ft square test material, however, this was not so and even after four wetting and drying cycles the panels did not behave in a regular manner. The distortions obtained were small, and the effect of the manufacturing variable was in every instance confused by the equally small but nevertheless significant distortion of the specially selected control material. This work was therefore discontinued and a more fundamental investigation started to determine the cause of the distortion of balanced plywood made from selected straight-grained veneers. The work has involved a study of the behaviour of the veneers during the spreading and pressing processes and is leading to a better understanding of the complicated changes which occur in the wood and which affect the stability of the finished product.

SHELLINESS IN GABOON VENEER

From time to time samples of gaboon veneer described as "shelly" have been received at the Laboratory. Shell varies in intensity but in a moderate form is shown by Plate 7. The defect is not immediately apparent, but if the piece is bent bow-wise with the slack* side of the veneer on the concave face, the shell "pops" and a separation occurs at about one-third of the thickness from the surface. If

* The 'slack side' of the veneer is that which in the log lies towards the heart.

shelliness is not noticed before the veneer reaches the hot-press in the final stage of plywood manufacture, extensive blistering will occur, and the boards will have to be rejected or cut down in size.

At first thought, it would seem that shell would be caused by some growth feature such as a form of ring shake or a line of weak tissue. This, however, has to be discounted when successive veneers peeled from a log show the same defect, particularly when it is seen that the rupture is parallel to the surface of the veneer and not the growth rings. An alternative explanation is that shelliness is induced by the setting of the knife and the nose bar in the veneer lathe.

A billet of gaboon already partly peeled commercially and known to contain shelly material was converted to sixteenth-inch veneer in the Laboratory's peeler, short lengths being run off with each of a variety of settings. Shelliness was made to appear, disappear and re-appear, being most marked with a large knife angle (i.e. an excessive clearance between bevel and billet) and a high nose bar (i.e. the application of pressure too far ahead of the cut).

It is probable that shelliness is rooted in some structural abnormality, but it is brought to light by the process of peeling and, conversely, can be largely avoided by correct settings of the knife and nose bar. Some earlier work on "shelly gaboon" was mentioned in the 1955 Report (p. 29), but it is now known that the material used then, although it contained other defects, was not truly shelly in character.

TRIALS OF TIMBER FOR PLYWOOD MANUFACTURE

Plywood manufacture trials have been made on muhuhu and pillarwood from Tanganyika, ceiba from Gold Coast, and on light red, yellow and white seraya, keruing and kapur from North Borneo.

The method by which these tests are carried out and the system for recording results[18] have been revised with the Plywood Research Panel, to incorporate the most modern ideas on plywood making.

STUDY OF PLANT AND EQUIPMENT

Before logs of most species can be converted into good quality veneer they have to be heated by immersing the billets in steam or hot water for perhaps several days. In an attempt to eliminate the need for this lengthy pre-treatment, a method was tried of heating the billet while in the lathe and during the actual process of peeling. A number of fine steam jets, at a pressure of 100 Lb/sq. in., were arranged to play on the log immediately ahead of the nose bar and up the flat side of the knife directly into the cut. They certainly heated the veneer, but the effect probably occurred after the cutting had taken place as there was no improvement in veneer quality over that obtained by cold cutting. The work has been discontinued.

A few years ago, the clipper for dealing with green veneer was very simply converted to pre-selector operation, but trouble was subsequently experienced with the mechanical clutch. This has since been replaced by an electric clutch-brake of English manufacture, and by its means, speed of operation has been increased from 140 to nearly 200 cuts per minute, which has enabled the conveyor speed to be increased from 30 to over 40 ft/min when operating on cuts 3 in. apart. With the electric clutch, repeatability of sizing has improved, and on an average width of 66·5 in., 90–95 per cent of the pieces lie within $\pm 0{\cdot}1$ in., this being the overall figure including slip of veneer on the conveyor.

RADIO FREQUENCY HEATING STUDIES

The work on the radio frequency heating of glued joints has continued and a report[19] has been issued on the application of this type of heating to a batten-to-plywood joint. Fig. 3 shows, for various electrode arrangements, the time required to obtain a set in the joint at four positions along the six-foot-long test

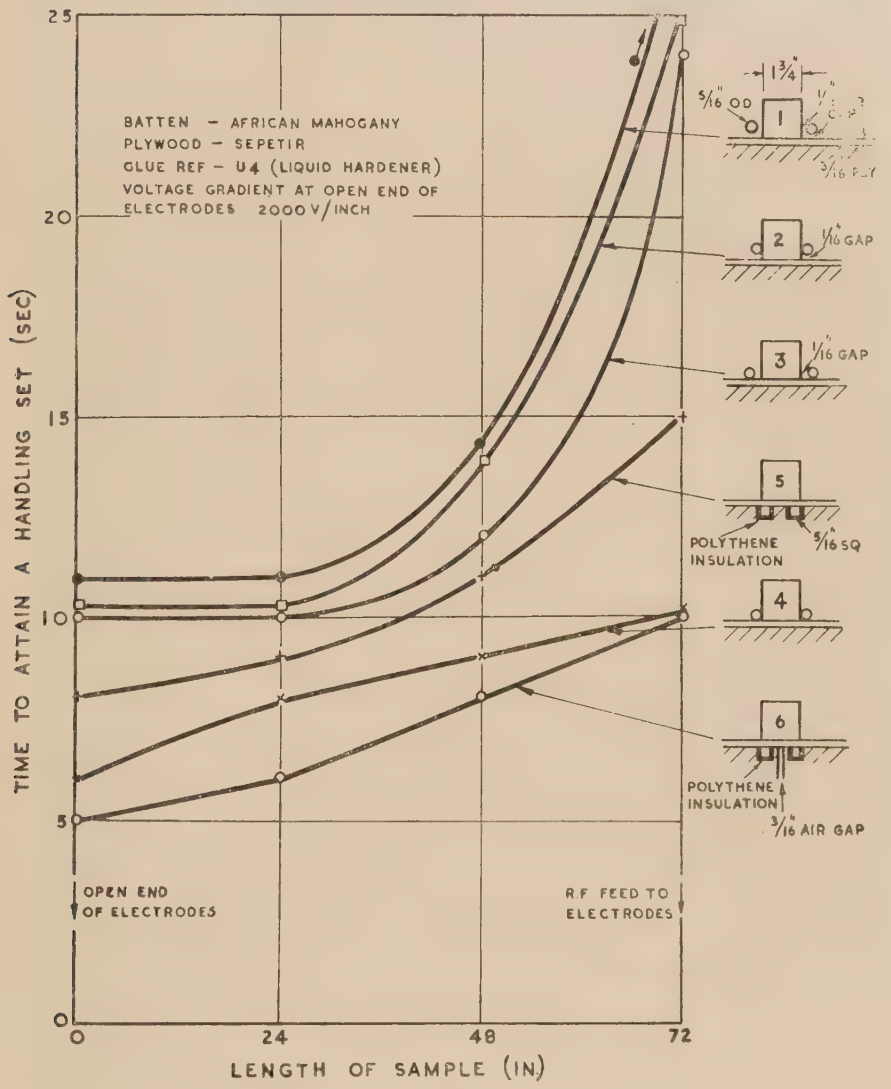


Fig. 3. Electrode arrangements

samples. For plywood three-sixteenths of an inch thick the most efficient arrangement is when flat electrodes are placed on the opposite side of the plywood to the glue layer. In this position the electrodes do not come into contact with the adhesive and the danger of arcing is minimized. Fig. 4 shows, for this electrode arrangement, the setting time for different thicknesses of plywood. For quarter-

inch material and above, the underneath-electrode position is shown to be less efficient and true glue line heating has to be employed with the accompanying danger of arcing resulting from contamination of the electrode.

Of the several variables investigated, the effects of open assembly time, bonding pressure and moisture content are unimportant compared with those of glue spread and the species of the batten. As glue spread increases the setting time of the adhesive decreases, but, if a thin glue and a high bonding pressure are

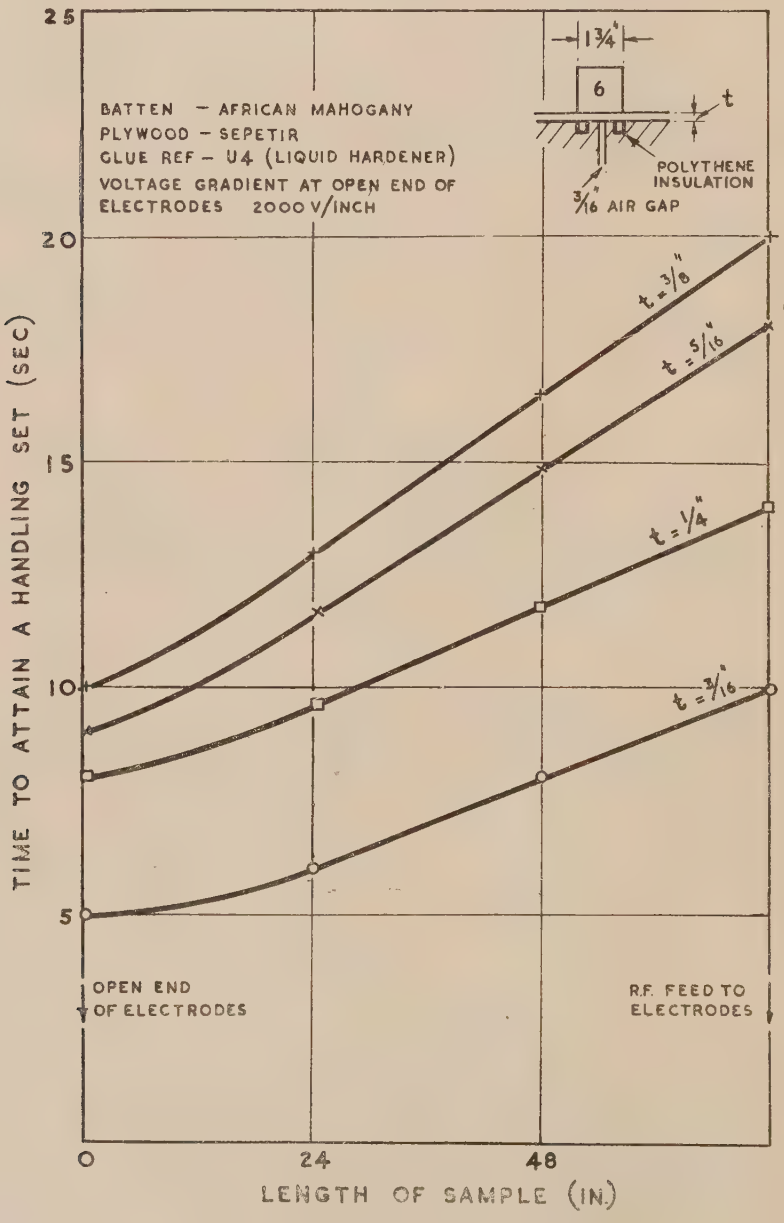


Fig. 4. Effect of plywood thickness

employed, then at high spreads the effect becomes negligible as nearly all the adhesive is squeezed out of the joint. From this aspect the more viscous powder-hardened glues are better than the thinner liquid-hardened adhesives. The setting time also seems to be proportional to the density of the batten. Faster sets can be obtained with the light species such as obeche than with the medium-density African mahogany. This is probably because there is a certain amount of selective heating of the glue and the temperature attained in the adhesive will depend on the rate with which the heat can escape into the adjacent wood, i.e. on the thermal conductivity of the wood. As the thermal conductivity increases with density a faster set would be expected with the light species.

Radio frequency heating has been applied to the manufacture of laminated beams. Plate 8 shows the laminae, 5 ft long and 8 in. wide, being spread with glue and assembled in the specially made jig. Flat side electrodes are employed so that selective heating of the glue can occur. Difficulty was experienced in assessing the uniformity of the heating between the electrodes. Thermocouples and temperature-indicating paints proved unsatisfactory but a visual indication method has been developed which depends on the rapid change of pH which occurs as the adhesive cures; this has been found applicable to many brands of cold-setting urea-formaldehyde glues in which the resin and hardener are mixed before use. Strips of universal indicator paper are laid on the glue line immediately after spreading and, turning green, indicate a pH of approximately 7. A sheet of thin cellophane is then laid over the spread surface and the beam assembled in the jig. At the end of the heating period the presence of the cellophane sheets allows the laminae to be separated and, if the adhesive has been set, the indicator paper will have turned bright red in colour indicating a pH of approximately 2. In this way it has been possible to determine the progress of the setting of the adhesive between the electrodes and along the length of the beam. The method should be of use in other investigations requiring a visual indication of the cure of cold-setting urea-formaldehyde adhesives.

An experiment on the ageing of glued joints set by radio frequency heating has completed five of its projected ten years and a report[20] has been issued. Laminated beech blocks were made using adhesives of the urea-, phenol-, and resorcinol-formaldehyde types and one special animal glue. The samples were set at room temperature and also under two levels of radio frequency heating and were then stored in a constant-temperature (25°C–77°F) room maintained at 60 per cent relative humidity. The joints were tested at intervals by measuring the force needed to separate the laminae. The results after five years show that joints cured in 60 seconds under radio frequency heating behave similarly to those set at room temperature but joints set in 10 seconds by radio frequency methods have a slightly lower failing load. The difference has existed from the beginning of the experiment and shows no tendency to increase.

ADVISORY WORK IN COMPOSITE WOOD

During the year 458 enquiries were received.

WOOD PRESERVATION

TESTING OF WOOD PRESERVATIVES

As mentioned in the Report for 1955 (p. 29) tests on creosote and other oil-type preservatives at varying concentrations should provide very useful information and during the year methods of preparing suitably impregnated specimens have

been examined. For a test of this type to be valid it is necessary to establish that the method used to vary the concentration of the oil in the wood gives a reasonably uniform distribution and does not set up any abnormal concentration gradients. In small-scale laboratory tests the method of varying the concentration of oil-type preservatives in the samples is by treating with graded concentrations in a volatile solvent; work has been carried out to see whether or not this method is suitable for the larger size specimens used in a field test. The solvents selected were benzene, toluene and xylene. These all give satisfactory solutions of creosote over the range required with practically no sludging. Field test specimens were treated under pressure with these solutions so that the wood was completely and uniformly impregnated. The solvent was allowed to dry off under normal atmospheric conditions and then the distribution of the creosote was measured. It was found that the evaporation of the solvent caused the creosote to move towards the surface of the wood, particularly along the direction of the grain. In some samples treated with a 5 per cent solution for example the concentration of creosote near the end-grain surface rose to about twice the average value while at the centre it fell to about one-fifth. Movement of creosote occurred also in samples treated with strong solutions, i.e. 30 per cent, but to a much smaller extent. Much the same results were obtained with all three solvents although there is a considerable difference in their relative volatilities.

An attempt was made to obtain more satisfactory distribution at the low concentrations by using a solution of not less than 25 per cent, so as to minimize movement of creosote on drying, and treating by an empty cell process instead of a full cell one to reduce the amount of solution absorbed initially. An empty cell process does not give the very uniform initial distribution of the impregnant that a full cell one does but it seemed probable that an empty cell treatment with a strong solution would give a better final distribution than a full cell treatment with a dilute one. So far, however, the results with this method have not been satisfactory.

PERMEABILITY OF TIMBER

Little is known about the effect of moisture content on the permeability of wood. There are indications from preservative treatment practice that softwoods, in particular Douglas fir, become appreciably more resistant to impregnation as they dry below their fibre saturation point. In order to obtain precise data on this relationship the permeability of specimens of two common softwoods, Scots pine and imported Douglas fir, has been measured as they were taken through a moisture content cycle ranging from above the fibre saturation point down to about 10 per cent and back again. In Scots pine some changes in permeability did occur, but they were not very great. In the radial direction there was an appreciable drop in the early stages of the drying followed by a gradual increase for the rest of the drying period. On rewetting, the permeability gradually decreased along approximately the same path but the initial drop was not regained. In the tangential direction there was no initial drop in permeability at the beginning of the drying period; it increased gradually from the start and decreased again to approximately the same value on rewetting. The permeability of Douglas fir varied in a similar way, but the changes were smaller.

FINISHES

In post-war building construction there has been an increased use of timber for cladding. The timbers employed for this purpose are usually chosen for their decorative value as well as for essential functional properties such as durability.

When exposed to the elements timber soon loses its colour and the surface becomes weathered unless it is given some protective finish. About two years ago service tests were started to assess the effectiveness of the various types of transparent finish which could be used on exterior woodwork. The results so far obtained with a few of the oil type finishes have recently been published[21]. They showed that, with the untreated controls, in the early stages of weathering the colour slowly fades to grey and numerous very fine checks, barely visible to the naked eye, develop all over the surface of the wood. The superficial fibres become brash and, in softwoods, some erosion of the softer springwood occurs. The most effective of the few oil finishes tried was linseed oil either neat or diluted with a solvent to reduce its viscosity so that it could be applied satisfactorily by brush. Neither treatment, however, is effective for very long and needs to be repeated periodically to maintain the appearance of the wood.

TRANSMISSION POLES

Creosoted poles which had been given remedial treatment against internal decay have been examined to ascertain the extent of the diffusion of the preservative salts. Analyses of borings confirmed previous findings[22, 23] that the salts diffuse into the wood satisfactorily at ground level but very little at about a foot or more above the ground. They suggested also that the amount of diffusion may be greater in poles where the creosote concentration is low.

PERMANENCE OF PRESERVATIVES

During the year some exploratory tests have been started to assess the permanence over long periods of preservative substances which have very low but perceptible vapour pressures and which are normally used for surface treatments by brush or dipping.

PLANT

During the year alterations have been made to the main pressure-impregnating plant. This is used principally for investigating specific treating problems on full-size timbers and it has been evident for some time that this work could often be carried out more efficiently if the plant were equipped with more accurate means of measuring and controlling the rate of absorption during treatment. This is true both when investigating the behaviour of material which can absorb preservatives very rapidly, such as Baltic redwood poles, and also with material such as Douglas fir, in which the rate of absorption is often exceedingly slow.

To obtain this improved performance new pumps and a new working tank fitted with a circulating pump, to facilitate accurate control of temperature, and a high sensitivity level gauge, have been installed. A pressurized working cylinder has been added which can provide automatic control of pressure during long treatments and accurate measurement of very low absorption rates.

ADVISORY WORK IN WOOD PRESERVATION

During the year 422 written enquiries were dealt with.

MYCOLOGY

A survey of recent work on timber decay, covering the literature that appeared between 1942 and the present time, was published during the year as a leader article in Forestry Abstracts[24].

CULTURE COLLECTIONS

The collection of standard cultures of fungi has been maintained in good condition, seventeen new isolations being added during the year: seventy-three cultures have been supplied to other research workers and firms. Cultures have been submitted for identification from the Forestry Commission, the Ministry of Agriculture, Fisheries and Food, and from the Agricultural and Forestry Departments of New Guinea and Kenya. Descriptions of fifteen additional species in culture have been prepared and transferred to perforated cards.

SOFT ROT INVESTIGATIONS

(a) *Water-cooling Towers*

Samples of decayed louvres from a German water-cooling tower, examined at the request of a worker in that country, were found to have been attacked internally by *Poria nigrescens* as well as decayed on the surface by micro-fungi. *Poria nigrescens* has also been isolated from samples of structural softwood and louvres from the mist eliminator system of a water-cooling tower in this country. This fungus has been noted as an important cause of decay of timber in cooling towers in the United States but has not previously been reported from towers in Europe.

In response to requests from workers in the United States and from the Central Electricity Authority samples of sequoia (Californian redwood) from American towers have been examined. The presence of soft rot in some of the samples was confirmed but bacterial attack or other unknown causes had brought about the deterioration in a greater number of the samples.

Soft rot has been observed in a sample of western red cedar from a water-cooling tower in this country.

(b) *Other Situations*

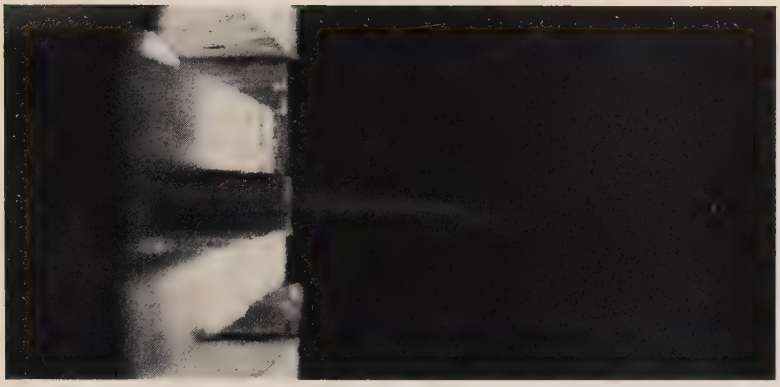
In addition to the examples noted above, soft rot has been found in the surface layers of Scots pine immersed for periods of up to 150 years in Norwegian rivers, and in preservative-treated timber from Sweden. Examples of incipient soft rot in standing trees have been noted in samples of *Lovoa klaineana* and in *Guarea* sp. In the former timber the decay was associated with heart shakes and in the latter with irregular tunnel-like cavities in the wood.

(c) *Laboratory Investigations*

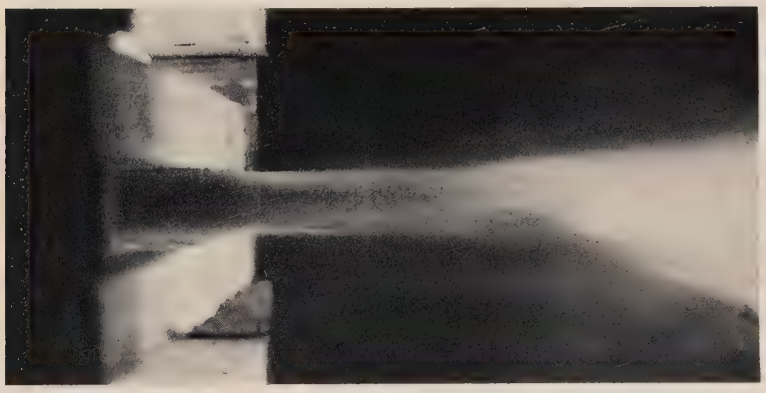
It has been shown that under the conditions of nutrition normally employed when carrying out tests involving decay of beech by *Chaetomium globosum* in the laboratory the weight of surface growths of fruiting bodies is directly proportional to the weight lost by the wood (Fig. 5). There are indications that when smaller amounts of additional nutrients are available to the fungus there is a sharp decrease in the formation of surface growths of fungus, so it appears that decay of wood by *C. globosum* is not necessarily accompanied by the development of fruiting bodies.

Long-term tests on the development of soft rot in timber samples exposed at high relative humidities and under water have now been in progress for one year. A small loss of weight has occurred in the samples exposed at relative humidities of 90 per cent or higher. Although samples freely exposed in the 90 per cent humidity room were originally sprayed with spores of *C. globosum* they have been extensively colonised by a species of *Phoma* which has been observed several times on timber samples exposed in this room during the past few years.

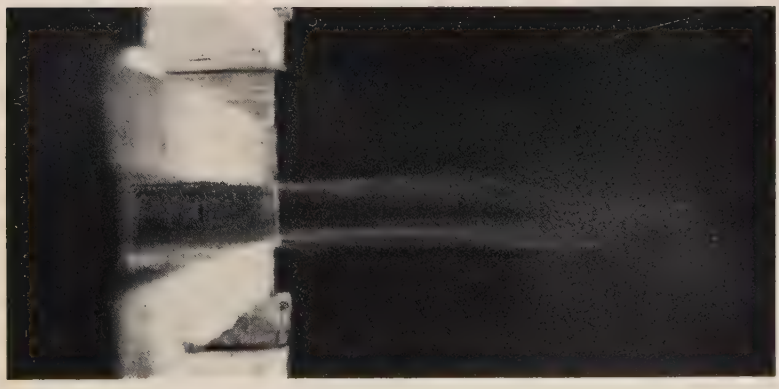
The investigation to determine the loss of strength of samples of beech wood exposed to the attack of *Chaetomium globosum* has been completed and a report



Immediately after emergence



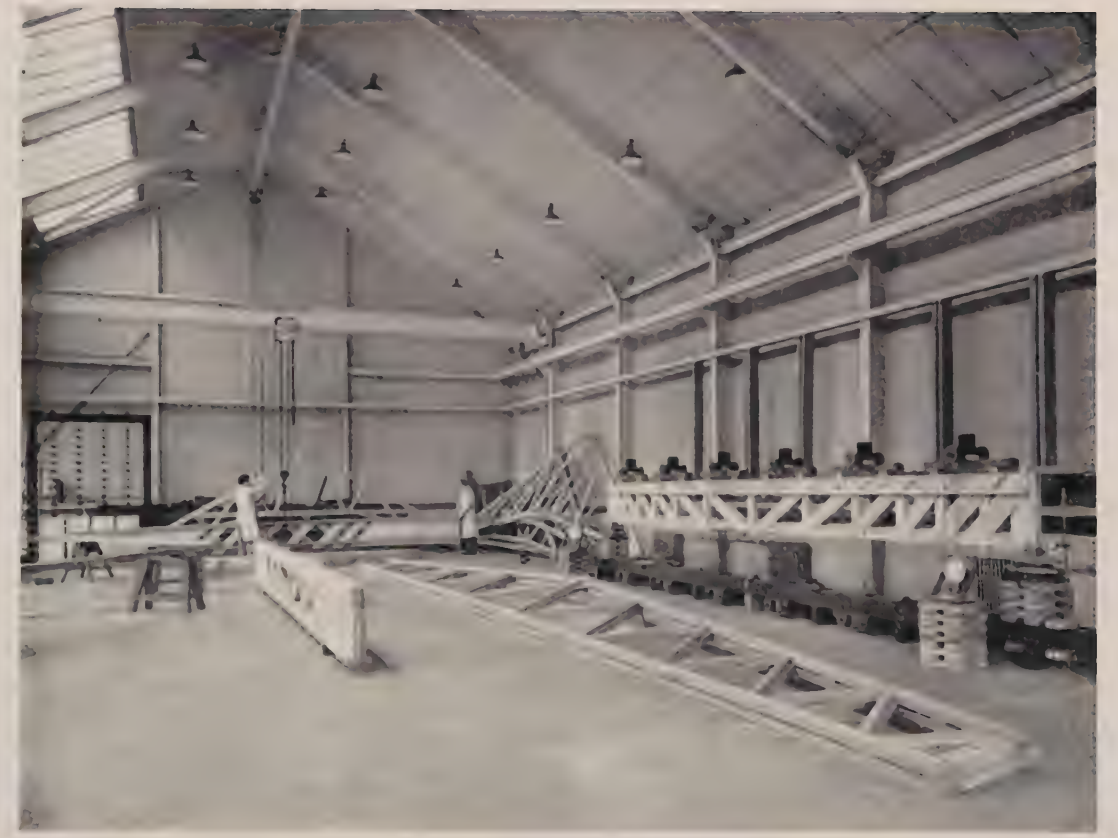
Three seconds after emergence



Six seconds after emergence

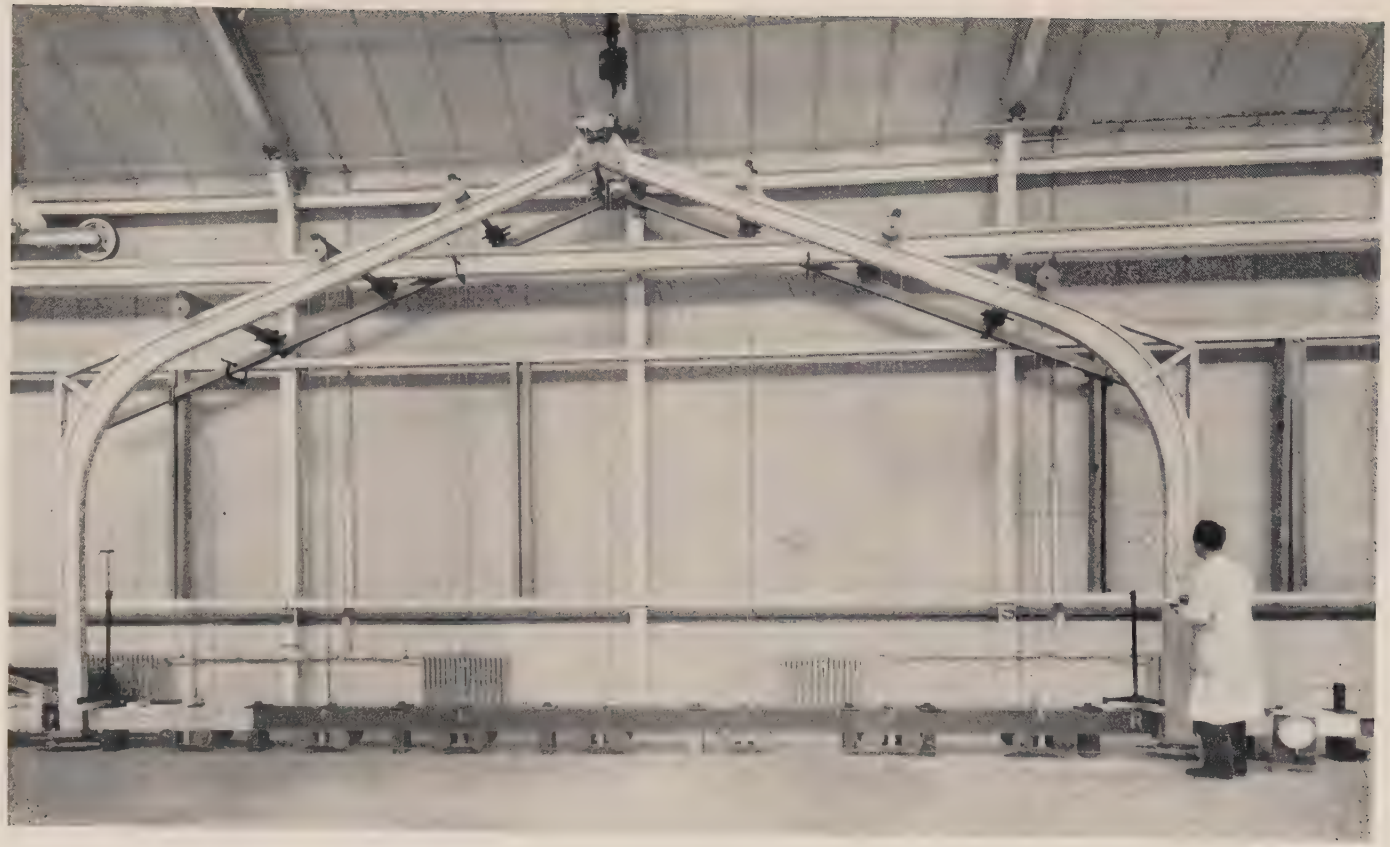
Artificial smoke showing effect of surface drag on air flow through a kiln pile

PLATE I



The structures testing laboratory

PLATE 2

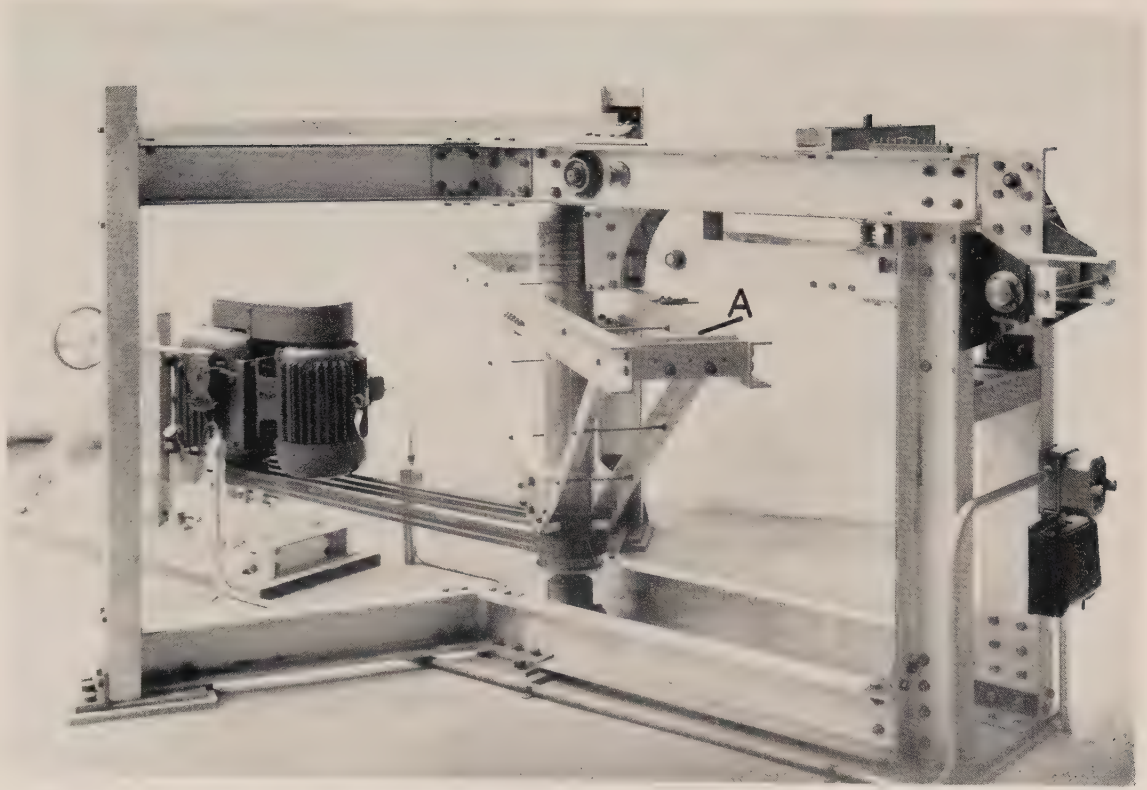


Testing a portal laminated arch

PLATE 3

Partly severed chip of sycamore wood ($\times 140$) (Chip thickness 40μ, cutting angle 20°)
The inset ($\times 700$, in polarized light) shows compression failures in cell walls)

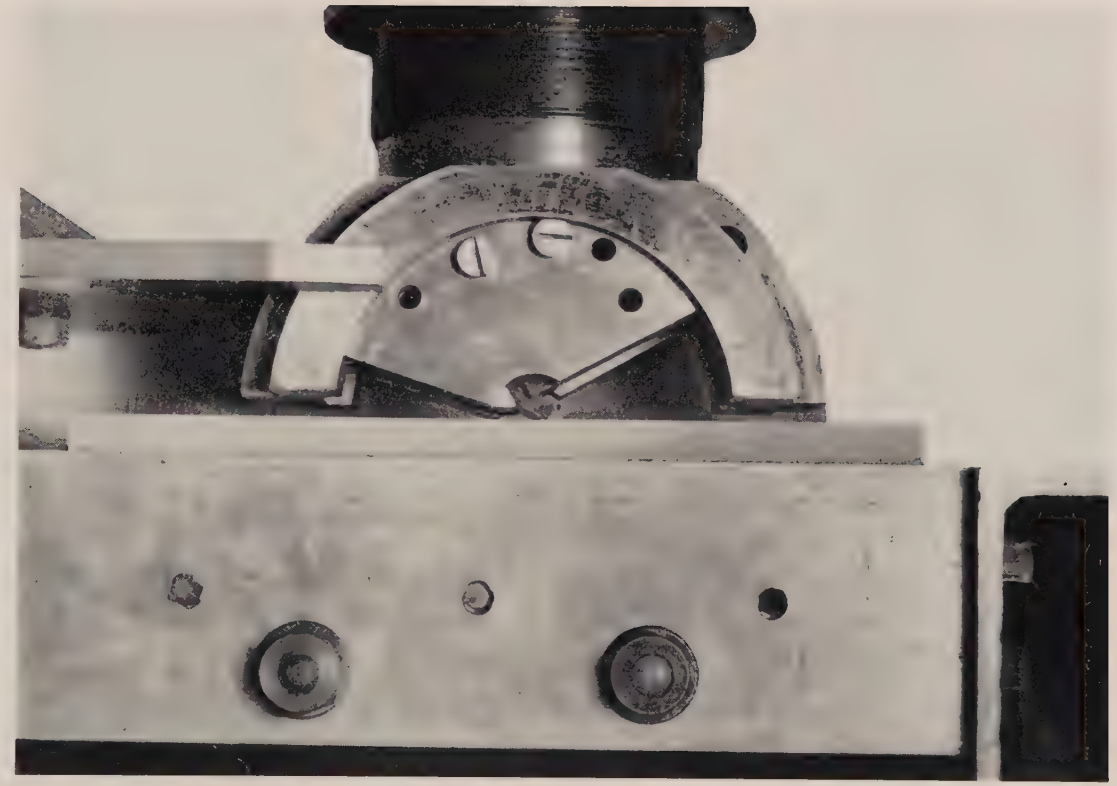
PLATE 4



"Whirling arm" machine for investigations on rectilinear cutting at high speeds

The wood specimen is clamped in the rotating arm at A and meets the cutter which is mounted on the vertical pillar

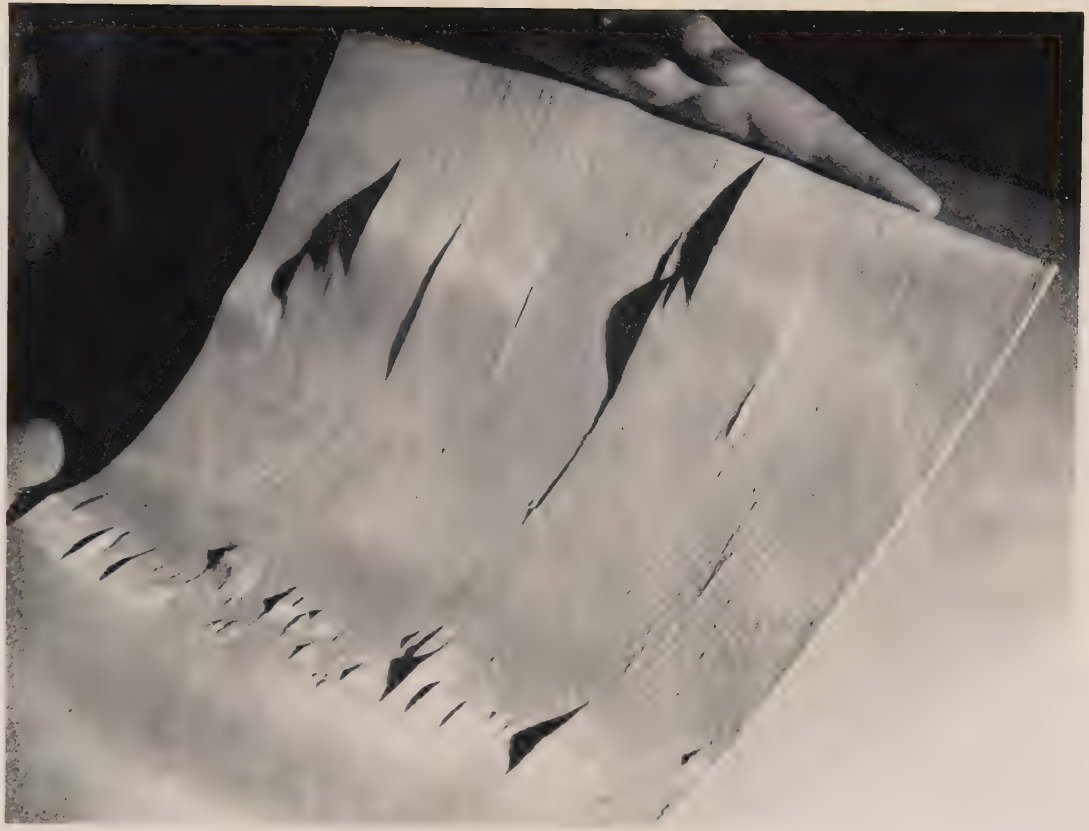
PLATE 5



Cutting head of "whirling arm" machine

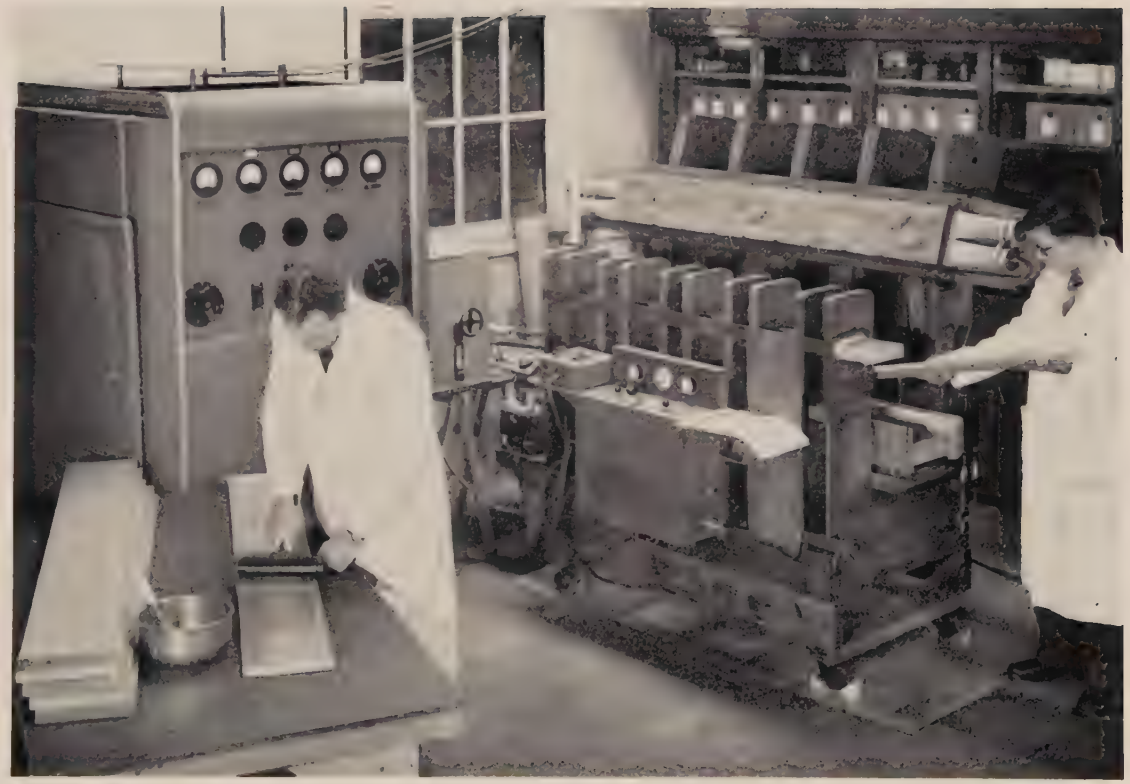
The timber sample moves under the cutter from right to left

PLATE 6



An example of "shelly" gaboon veneer

PLATE 7



Apparatus for the investigation of the manufacture of laminated beams

PLATE 8

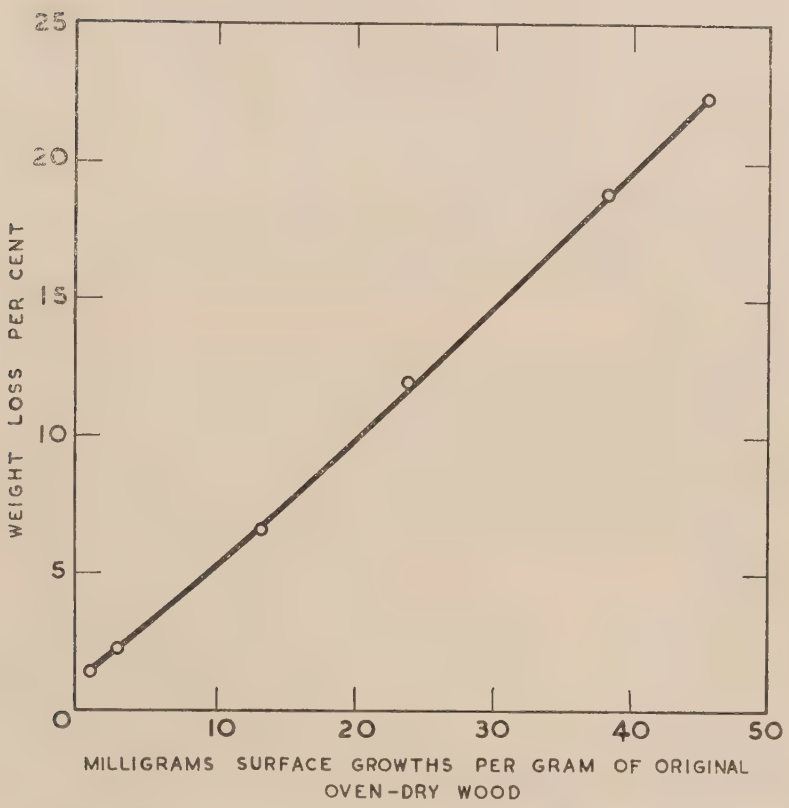


Fig. 5. Surface growths of *Chaetomium globosum* in relation to weight loss in wood

is being prepared for publication. Further material has been prepared for chemical analysis of wood severely decayed by *C. globosum.*

LABORATORY TESTS OF WOOD PRESERVATIVES

Applications from manufacturers of wood preservatives for laboratory tests on their products have increased in number and it is evident that the testing service provided by the Laboratory is of considerable value to the industry. In a number of instances modifications in the composition of the preservative have been made as a result of tests that have disclosed inadequate toxicity in the product. Full standard tests have been completed on four proprietary products and tests on nine products for surface application have been carried out for firms. In some of the tests the toxicity to *Chaetomium globosum* was also examined.

Laboratory tests have also been carried out on a number of other antiseptics including pyroligneous acid, which was shown to be quite ineffective against dry rot fungi.

Following on the observations reported last year that decay of wood by *Coniophora cerebella* appears to be stimulated by the presence of small amounts of sodium fluoride, an experiment was made to determine the range of concentrations over which this effect occurs. The results are shown graphically in Fig. 6, from which it will be seen that the rate of decay increases with increasing

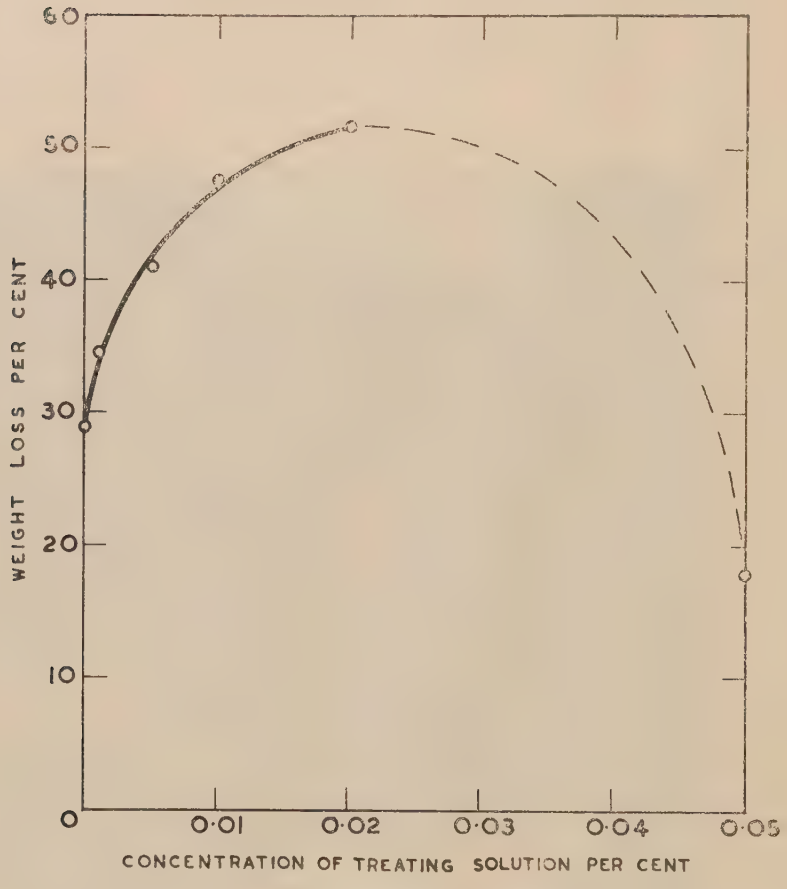


Fig. 6. Decay by *Coniophora cerebella* of Scots pine sapwood treated with low concentrations of sodium fluoride

concentration of fluoride up to 0·02 per cent, while at 0·05 per cent a toxic effect becomes evident. An explanation of this stimulation which is also shown by *Poria vaporaria* is being sought and it is planned to study the rate of respiration of these fungi in the presence of minute amounts of sodium fluoride.

In co-operation with two other laboratories a series of tests designed to compare the results obtained using various soils in the so-called soil/block method have been carried out for the British Standards Institution Committee that is revising the standard laboratory method for testing wood preservatives, and a joint report on these has been submitted to the Committee. In general, the results show that the toxic limits established when different soils are used are well within the variation found between tests on the same soil carried out in different laboratories. Broadly speaking, the toxic limits are similar to those obtained when the test fungi are cultivated on malt agar. *Coniophora cerebella* and *Poria vaporaria* grow rather better in the soil/block tests, while *Polystictus versicolor* and *Lentinus lepideus* grow as well or better over malt agar. Co-operative tests on the rate of evaporation of creosote from test pieces of various sizes are being carried out for

the information of the Committee. Further tests of the toxicity of wood preservatives to *Chaetomium globosum* have been made using the Abrams' mycelial mat method. While it has been confirmed that this fungus is more resistant to pentachlorphenol than the ordinary Basidiomycetes it does not show a greater resistance to creosote or copper naphthenate than the most resistant of the usual test fungi.

Since soft rot is of economic importance chiefly in situations where considerable leaching is experienced, in order to ascertain the practical value of standard wood preservatives for prevention of soft rot a series of tests has been started in which the test blocks are submitted to leaching before exposing them to attack by *C. globosum.*

The decay resistance of plywood made from veneers treated with water-soluble preservatives and bonded at the Laboratory has been examined. It has been shown that exposure of test pieces by the agar/block method is unsatisfactory as water-logging occurs but that satisfactory control of moisture conditions is obtained when the soil/block method is used. It has also been shown that unless a leaching procedure is carried out on some of the test blocks before exposing them to attack by wood-destroying Basidiomycetes, untrustworthy results may be obtained because of the temporary protection given by some glues.

LABORATORY TESTS OF NATURAL DURABILITY OF TIMBERS

Standard laboratory tests on the natural resistance to decay of the following timbers have been completed:

muhuhu, kapur, keruing, light red seraya, yellow seraya, white seraya and pillarwood.

Further tests on various samples of African mahogany have confirmed that a considerable variation in decay resistance exists between the inner and the outer zones of the heartwood, the latter being always the more durable; a note summarizing these results has been submitted for publication in the Empire Forestry Review.

The rate of absorption of moisture by test pieces of various woods in contact with agar has been studied and it has been found that some of the denser woods take many weeks to reach an equilibrium.

An unusual case of premature decay of western red cedar boxes that had been used for raising freesia bulbs is being investigated. A fungus resembling *Merulius sclerotiorum* has grown on pieces of the decayed boxes that have been kept in damp places. Samples of the soil containing the bulb manure have been found to stimulate the decay of wood by *Chaetomium globosum.* Experiments are also in progress to determine the effect of leaching on the durability of western red cedar.

DRY ROT INVESTIGATIONS

Further tests have been made with fungicides for the sterilization of brickwork infected with the dry rot fungus. A cement paint containing calcium pentachlorphenate was found to be effective.

DECAY OF TIMBER IN BOATS

The effect of salt content on the decay resistance of wood is being studied. The resistance to decay and the salt content of samples of elm taken from the *Cutty Sark* have been examined.

H.M.S. *Victory* has been inspected to see whether active decay is likely to be proceeding at the present time.

It has been suggested that the addition to the bilge water of a very slightly soluble fungicide may help to prevent decay in the timbers and planking of boats. Water from the bilges of an 80-ton sea-going vessel in which a nylon bag containing pentachlorphenol had been suspended for five months was found to be toxic to wood-rotting fungi. Laboratory tests have shown that timber can be protected against attack by wood-destroying fungi by immersion in water saturated with pentachlorphenol, but a very long period of immersion may be required when the proportion of wood to water is large. On the other hand, rapid protection of small test pieces can be achieved under laboratory conditions in a four-gallon tank.

SAP-STAIN AND MOULD INVESTIGATIONS

Enquiries were received regarding the cause of sap-stain in Maracaibo boxwood logs imported in 1955 from Venezuela for the manufacture of rulers and handles of good quality tools, for which purposes any staining is objectionable. It was found that the stain was caused by *Diplodia natalensis* and related species which are known to occur commonly in the tropics. Investigations have shown that although the logs may appear to be free from visible stain on arrival, infection is already present in and just below the bark. This infection may continue to spread internally in the logs after they have been cut into "half rounds" without any stain being seen on the surface. Complaints about this type of staining were received after the hot summers of 1947 and 1955 and in the light of this experience it would seem advisable either to convert immediately after receipt or to sterilize in a kiln logs received at the beginning of the summer. It has been shown experimentally that the staining fungus in a half-log of average dimensions ($8\frac{1}{2}$ in. diameter) is killed after four hours at 65°C in a saturated atmosphere. Laboratory experiments are in progress to determine the precise temperature at which the fungus can be killed in naturally infected timber.

Experiments to determine the loss in strength caused in ramin by *Diplodia* stain have been carried out and a report is being prepared.

The effectiveness against sap-stain of various proprietary formulations of sodium pentachlorphenate and sodium orthophenyl phenate has been tested on behalf of a firm. The comparative toxic limits of these two fungicides to four staining fungi growing on malt agar have been determined.

The resistance to moulds of fire hose made of Italian hemp and of plastic fire hoses made with "Terylene" and nylon wefts has been examined on behalf of the Joint Fire Research Organization.

PREVENTION OF DETERIORATION IN LOGS

Earlier experiments showed that good protection can be given to beech logs awaiting conversion by treating the ends and exposed wood with a fungicidal solution plus a waterproof end coating. A further test has been started using gasworks tar, which combines a certain degree of toxicity with some moisture-retarding properties.

ADVISORY WORK IN MYCOLOGY

The number of enquiries, 987, dealt with by letter has been somewhat lower than in the previous year, but there is a tendency for a higher proportion of enquiries than formerly to come from firms rather than from private individuals. It is evident that the great post-war increase in the prevalence of dry rot has been in some degree overcome.

Among the more interesting enquiries received was one relating to the contamination of beer in casks made of Persian oak. It was found that the wood was infected with a fungus, *Stereum subpileatum*, which produces a strong sickly sweet aroma, the chemical nature of which has been identified at the London School of Hygiene and Tropical Medicine. There is little doubt that the infection occurred in the standing tree and survived in the barrel heads, which are not normally steamed. Recurrence of the trouble could be prevented by steaming the barrel heads along with the staves before the latter are bent during the manufacture of the casks.

An increasing number of enquiries relate to staining and discoloration in timber. The fashion for light-coloured furniture with a natural finish means that greater importance is attached to the clean light appearance of pale-coloured woods, and discolorations that were formerly overlooked now assume importance.

ENTOMOLOGY

LYCTUS POWDER-POST BEETLES

Starch Depletion in Kiln-dried and Air-dried English Oak in Relation to Infestation

Starch grading of matched samples of kiln-dried and air-dried oak has been completed but the results have not been fully analyzed. Preliminary conclusions indicate that there is no significant difference in the extent of starch depletion brought about by the two methods of seasoning. Considerable variation has been noted within each group in boards cut from different logs. Samples are now awaiting exposure to *Lyctus* attack in order to correlate starch grading observations with actual infestation.

Infestation in Oak Block Flooring

Reports are occasionally received of attack by *Lyctus* in oak block flooring, and an experiment was set up in 1953 to note the progress of attack in sapwood in oak block flooring under conditions in a centrally heated building. The results show that *L. brunneus* is able to infest flooring at various stages of finishing, e.g. after sanding, oiling or wax polishing. Setting of blocks in hot bitumen has been shown to have no sterlizing effect on insects already within the timber. Spread of attack in polished flooring from infested to sound blocks has occurred to a slight extent, probably because the insect has been able to lay eggs in crevices between adjacent blocks, particularly where shrinkage after laying led to exposure of unpolished wood. The minimum life-cycle of *Lyctus* under the condition of the experiment was seven months but scattered emergence occurred throughout the year.

It is concluded that when *Lyctus* infestation in newly laid oak flooring does occur it is usually the result of attack in the blocks before installation, but that it is possible for infestation to commence during finishing of the flooring and even after final wax polishing if a source of the beetles is present.

Prevention of Infestation in Sawn Logs

No attack by *Lyctus* has taken place in sawn logs of English oak boards treated in May 1955 by a 10-second dip in oil/water emulsions of dieldrin and BHC at concentrations of 1·0 and 0·5 per cent, and DDT at concentrations of 2·0 and 1·0 per cent. Infestation was present in the untreated control log, in which exit holes were noted in about one-third of the boards.

COMMON FURNITURE BEETLE (*ANOBIUM PUNCTATUM*)

Investigations on this insect have been continued as a major research project and have comprised studies of the behaviour of the adults and of the conditions governing the nutritional value of wood for the growth of the larvae.

Behaviour and Life-history Studies

Further investigations on emergence from the birch plywood mentioned in the Annual Report for 1955 (p. 35) have confirmed that the beetles prefer to emerge towards the light. It has also been found that after emergence the insects continue to exhibit a tendency to move from dark positions towards those of higher daylight intensity.

Additional studies of infestation of birch plywood made up in 1953 with urea-formaldehyde glue have been hampered by the small number of eggs laid on experimental material, including controls of solid birch, but there are indications that the repellent effect of this glue, previously noted, may be reduced as it ages.

It has been confirmed that in suitable wood, e.g. the outer zone of Scots pine sapwood, larvae of this insect develop much more rapidly under incubator conditions of 22°C and 86 per cent relative humidity (equivalent to a moisture content of the order of 20 per cent) than out-of-doors but that pupation rarely occurs under such conditions. In the laboratory where temperature and humidity were not controlled, it has been found that egg-laying and hatching will take place but that initial larval boring ceases at an early stage, apparently after the onset of central heating, resulting in a fall in moisture content, rendering the wood unsuitable for the continued development of the young larvae.

Nutrition Studies

In continuation of investigations on the nutritional value of wood for the growth of the larvae, a series of zoning experiments with Scots pine, similar to those previously carried out with Corsican pine (see Annual Report 1954, p. 33) has been completed. Sapwood discs cut from a freshly felled sapling of Scots pine were divided into three zones and exposed to attack. The results in relation to larval development were similar to those obtained with Corsican pine, a decreasing gradient of suitability of the wood being noted from the outer to the inner sapwood. A slight fall in nitrogen content and a rise in resin content occurred across these zones: these factors together may explain the differences in larval growth rates in the three zones.

Sound English oak heartwood is not normally attacked by this insect. Confirmation of its unsuitability was obtained by a similar experiment in which three zones of heartwood of this timber were exposed to attack; infestation did not occur in any zone.

An experiment to investigate the effect of different methods of drying the outer zone of Scots pine sapwood upon its suitability for larval growth has shown that it was more suitable when air dried out-of-doors than when kiln dried, as judged by the average weight of larvae and their survival rate.

An explanation of these results has again been sought by extracting with acetone or with water the sapwood and outer zone of the heartwood of English oak, and sapwood zones of Scots pine, to compare with the results previously obtained with Corsican pine. None of the solvents rendered oak heartwood suitable for attack. Acetone extraction rendered the sapwood of oak and the outer and middle zones of Scots pine more suitable for larval development than untreated controls, no doubt due to removal of tannin and resin respectively.

Extraction with water appeared to produce a more marked effect in the Scots pine than in the oak. Treatment of the former at 30°C reduced the suitability of the wood as was noted in Corsican pine treated at 60° C; much larger larvae were, however, obtained in the English oak sapwood extracted at 60°C. Comparison of the effect of water extraction of the kiln-dried and air-dried Scots pine sapwood showed a lower survival in the kiln-dried material.

Owing to the negligible quantities of free sugars (determined chromatographically) in the water extracts of Scots pine sapwood, it would seem that some undetermined water-soluble substances necessary for normal larval growth may be removed by this treatment.

Effect of Fungal Decay

Additional data obtained from samples of English oak sapwood decayed by white rot fungi to losses in weight of 26–38 per cent and then exposed for egg-laying by *Anobium* have confirmed that not only do larvae grow more quickly in decayed wood but that this effect is more marked at the higher losses in weight. In connexion with earlier observations that *Anobium* larvae can feed and grow in Scots pine heartwood decayed by the brown rot, *Coniophora cerebella* (see Annual Report 1953, p. 37) it is of interest to record that two large larvae were found still feeding in this material after six years, indicating the potential risk of damage in heartwood which may be caused by this insect in the presence of fungal decay.

Further material of Scots pine, walnut, beech, oak and yew kept under incubator conditions (22°C and 86 per cent r.h.) for 5–6 years have been examined. It has been found that even where the larvae have reduced the samples to powder, starvation has not forced pupation, confirming previous indications that these conditions of temperature and humidity are unsuitable for the completion of the life-cycle of the insect.

DEATH-WATCH BEETLE (*XESTOBIUM RUFOVILLOSUM*)

A start has been made in re-establishing laboratory cultures of this insect under natural conditions out-of-doors and at controlled temperature and humidity. This material is required not only in connexion with investigations on new methods of control but also for work on the relationship between moisture content of decayed wood and its suitability for attack by this insect.

The Laboratory has again maintained close contact with the Chief Architect's Division, Ministry of Works, in connexion with the annual records of death-watch beetle emergence in Westminster Hall and is indebted to the Architect-in-Charge for arranging for daily collections of the beetles to be sent to the Laboratory for experimental work. Analysis of the data obtained from such collections over a period of years has proved of immediate practical value in assessing the location and extent of activity of the insect in relation to insecticide treatments and repairs.

H.M.S. Victory

On the recommendation of the Forest Products Research Laboratory and the Pest Infestation Laboratory, a third fumigation of the ship with methyl bromide was carried out in May, 1956. As in 1955, the treatment was undertaken halfway through the emergence period of the death-watch beetle in order to obtain further information on the effect of the two previous fumigations. The Laboratories co-operated in assessing the results by placing specimens of insects in various positions on the ship and by gas sampling during the treatment. Analysis of the final

results obtained is not yet complete but all death-watch beetle eggs and larvae placed in the open were killed and there is evidence that in some positions insects placed within test samples of short lengths of sound oak heartwood, 4×4 in. and 6×6 in., were also destroyed.

Comparison of the numbers of death-watch beetles collected on the ship during the emergence periods 1953–56 suggests that the fumigation treatments have been markedly effective in reducing the death-watch beetle population:

1953	5200	Collected April–June; no fumigation
1954	938	Collected April–June; fumigated before emergence
1955	685	Collected April–mid May before fumigation
	204	Collected mid May–June after fumigation
1956	207	Collected April–mid May before fumigation
	23	Collected mid May–June after fumigation

HOUSE LONGHORN BEETLE (*HYLOTRUPES BAJULUS*)

Occurrences

Seven further instances of attack in buildings in parts of Surrey where the insect is known to be prevalent have come to the notice of the Laboratory during the past year. In addition, infestation in packing cases has been reported from Haworth, Yorks, and from Oxford. An instance of active attack in a door in a house in Norwich six years after erection has been noted but no information could be obtained on the origin and age of the timber used in its construction.

Nutrition Experiments

Variations in rate of growth of first stage larvae when introduced to matched samples kept under similar conditions have been a complicating factor in experiments hitherto undertaken to determine the optimum requirements for larval development. Further work has been carried out to attempt to establish a standard for assessing the nutritional value of wood in relation to attack by this insect. Discs of freshly felled Scots pine were zoned along every sixth annual ring and cut into blocks into which newly hatched larvae were inserted in the springwood of the rings. The blocks were kept at 25°C and 75 per cent relative humidity for about a year when the larval population, individual and total weights of larvae and the extent of disintegration of the samples (weight of frass) were determined. Wide variations both in larval weight and extent of attack were again noted and it has not yet been possible to relate condition of wood, size and number of larvae, with extent of attack.

A new series of experiments has been carried out to determine the effect of extracting similar Scots pine with acetone or water upon its suitability for larval development. Discs were extracted with acetone at 56°C and with water at 30°C in contrast to 100°C in the earlier work, when the possibility of hydrolysis of the wood may have complicated the results. Newly hatched larvae were introduced to the samples cut from each zone and again kept at 25°C and 75 per cent relative humidity. Examination of blocks from the outer zone after 30 weeks for comparison of larval weights in treated and untreated samples has confirmed previous indications of the unsuitability of the water-extracted material and has shown that acetone extraction has a slightly inhibiting effect. An explanation of these results is being sought by chemical analyses of the untreated wood and of the extracts. Although full results are not yet available, it appears that the nitrogen content of the wood is of prime importance in determining its suitability for larval

development. Further light on this possibility should be obtained from examination of the material cut from other zones.

An investigation has begun upon the effect of varying moisture content of wood on its suitability for infestation by the house longhorn beetle; some preliminary work is in progress upon the effect of steaming Scots pine sapwood at 100°C for 8 and 16 hours.

AMBROSIA (PINHOLE BORER) BEETLES

The Oak Pinhole Borer, Platypus cylindrus

Studies of the life-history and fungal associations of this insect have been continued by an officer of the West African Timber Borer Research Unit. From visits to woodland sites at Tubney, near Oxford, and Winslow, Bucks, a full picture of the natural life-cycle has been obtained. The cycle of development may take either one or two years depending upon several factors, including the time of initial infestation, i.e. whether early or late in the emergence period, and upon the condition of the host log or stump. The relatively long emergence period was emphasized in 1956 when it began in the first week of July and extended to mid-September, the peak emergence being in late July. Further observations have been made on the behaviour of the insects during emergence and initial boring and it has been shown that the male, which invariably starts the boring, introduces the typical ambrosial lining into the tunnel before the advent of the female[24a].

Work on the fungi associated with *P. cylindrus* continued throughout the winter 1955–56, and the resulting culture collection has been maintained. A species of yeast-like fungus, an Endomycete, has been consistently isolated from normal tunnels, where it grows in the finely divided wood lining the tunnel. Other fungi are often isolated and the work of evaluating their importance for the microhabitat is continuing. Some information on the succession of fungi in older and abandoned tunnels has been obtained.

It has been noted that oak recently attacked by *P. cylindrus*, and therefore in some way attractive to this insect, had a pleasant smell often absent from uninfested wood. Graham and Werner (1956)[25] have devised a method for the extraction of volatile organic compounds from softwoods by passing nitrogen over heated finely divided wood and condensing the vapour in a dry ice trap. A similar technique has been developed at the Laboratory for use with oak, and aromatic extracts have been prepared from wood known to be attractive to *P. cylindrus*. Scent traps containing samples of extract were placed in areas where the insect was emerging but owing to poor weather conditions emergence was at a very low level. No *P. cylindrus* was caught in these traps but it is intended to repeat the experiment next season on a larger scale throughout the whole of the emergence period.

Investigations on Other Ambrosia Beetles

During visits to timber yards, several different species of Scolytidae and Platypodidae have been collected from tropical hardwoods and isolations from ambrosia fungi made and added to the culture collection. Ambrosia fungi have also been cultivated from actively infested tropical hardwoods at Princes Risborough. Interesting similarities have been noted in the structure of the ambrosial lining associated with different ambrosia beetles.

Investigations in West Africa.

The Officer in Charge, Entomology Section, has continued to be responsible for the scientific direction of the work of the West African Timber Borer

Research Unit. Programmes of research, progress reports and publication of results have been discussed by correspondence and with the Officer in Charge of the Unit. A general account of the investigations carried out in the Gold Coast and Nigeria during the past three years together with interim recommendations for treatment of logs for the prevention of attack has been published in papers read before the Annual Convention of the British Wood Preserving Association in Cambridge[26] and at the 10th International Congress of Entomology, Montreal, August 1956.[27]

LABORATORY TESTS OF WOOD PRESERVATIVES

Larval Transfer Technique

Work has been continued using this method of comparing the toxicity of water soluble preservatives to larvae (1·0 to 2·5 mg) of the common furniture beetle and newly hatched larvae of the house longhorn beetle.

Borax

Results show that in treated blocks cut up six months after insertion of larvae of the common furniture beetle, none survived in those having a retention of 2·4 mg/c.c.; living larvae were present in blocks containing 0·68 mg/c.c. or less. A retention of 0·34 mg/c.c. was sufficient to prevent survival of larvae of the house longhorn beetle but after 12 months, survival was noted in blocks with a retention of 0·068 mg/c.c.

Other Preservatives

Fluor Chrome Arsenate Preparation. In blocks examined six months after insertion of larvae of the house longthorn beetle, no survival was noted in those with a retention of 3·4 mg/c.c. Living larvae were, however, found in material containing 1·4 mg/c.c.

Acid Cupric Chrome Preparation. A retention of 7·1 mg/c.c. was necessary to prevent survival of larvae of the house longhorn and common furniture beetles, whilst treatment at the rate of 1·4 mg/c.c. was insufficient to prevent larval boring by both species in samples examined six months after insertion in the treated blocks.

Egg-laying

Death-watch Beetle. Tests have been carried out with a number of proprietary preparations, applied as a 10-second dip, to ascertain their efficacy for the prevention of egg-laying and successful penetration of first stage larvae of the death-watch beetle in samples of decayed oak sapwood. Of the six materials tested based on metallic naphthenates, chlorinated naphthalenes, pentachlorophenol, lauryl pentachlorophenol and sodium pentachlorophenate, only the last mentioned failed to prevent egg-laying and boring of newly hatched larvae.

Lyctus brunneus

Pentachlorophenol. In continuation of tests with various concentrations of pentachlorophenol, a 1-minute dip treatment in a 5 per cent solution in chloroform failed to prevent attack in English oak sapwood after two years' storage under laboratory conditions. Further tests are now in progress with solutions in white spirit using dehydrated castor oil as an anti-blooming agent.

Other Preservatives. Exposure tests using oak sapwood treated with aldrin and dieldrin in different formulations and concentrations, BHC and lauryl pentachlorophenol, have been continued to ascertain the duration of effect of these materials as contact insecticides.

TOXICITY OF METHYL BROMIDE TO WOOD-BORING INSECTS

With the continued co-operation of the Pest Infestation Laboratory, a further series of experiments has been undertaken to supplement earlier data on lethal dosages (concentration/time products) for adults and eggs of the death-watch and common furniture beetles. In addition, experiments have been carried out with first stage larvae of the death-watch beetle after their establishment in decayed oak sapwood. The information sought is of particular importance in relation to the results of the fumigation of H.M.S. *Victory*.

DESTRUCTION OF WOOD-BORING INSECTS BY RADIATION TREATMENTS

Gamma Rays

Laboratory experiments have been continued in co-operation with the Radiation Chemistry Group of the Atomic Energy Research Establishment, Harwell, to confirm and amplify the data summarized in last year's Report (p. 41). The results as a whole are promising and indicate that although the high dosages required to kill larvae are not likely to be practical or safe to use for eradicating infestations in buildings, arrested development of larvae and sterilization of adults of the common furniture, death-watch and *Lyctus* beetles can be achieved at comparatively low dosages of the order of 8000 r. In view of the high resistance, shown by experiment, of mature eggs of the common furniture and death-watch beetles, the application of gamma rays offers little hope of their practical use for the destruction of eggs. A summary of this work has been published[27a].

Further experiments are planned and include an extension of the investigations at Harwell to develop methods of application of gamma ray treatments in practice.

High Frequency Electric Currents

This work has been continued in co-operation with the British Electrical and Allied Industries Research Association using oak sapwood and obeche plywood infested with *Lyctus* powder-post beetles. In order to sterilize such insect-infested wood by heating with high frequency electric currents, the temperature must be raised to a minimum of 70°C. Over-heating at the wood surface may result from attempts to attain this temperature at depths within the timber, particularly when using the stray field method with a single positive electrode. Laboratory experiments have been undertaken to investigate the effect on different types of surface finish when wood blocks were submitted to high frequency treatments sufficient to attain the required sterilization temperature at depths of up to 1 in. It was found that with a wax polish no damage took place, simple re-polishing after treatment resulting in an improved lustre. French polish was visibly affected at temperatures of about 140°C and needed some re-polishing after treatment. At temperatures of about 100°C a cellulose finish started to bubble and complete re-surfacing was necessary. Damage to surface finishes could be minimized by moving the electrode slowly across the wood, and experiments by the Research Association are continuing to investigate the development of a mobile electrode on a flexible cable for the treatment of timber, e.g. panelling in a building.

Infra-Red Rays

The possibility that heat sterilization of insect-infested timber *in situ* by means of infra-red lamps might be more practicable than treatment by high frequency currents has been considered and a few preliminary experiments carried out in co-operation with a large firm of electrical manufacturers. Sheets of $\frac{3}{8}$ in. obeche 3-ply infested with *Lyctus brunneus* were heated by batteries of infra-red lamps

arranged to give a heating intensity of 360 watts per sq. ft on the surface of the test samples. The heat energy released on the surface is conducted through the wood in a diminishing temperature gradient which was measured by thermocouples on the top and under surfaces. Under these conditions of experiment, it was found that a 10 minute treatment was required to reach a temperature of 55°C on the under surface of the plywood and obtain complete larval mortality. Experiments are continuing to determine the relations between different surface heating intensities, exposure periods and lethal temperatures.

ADVISORY WORK IN ENTOMOLOGY

During the year 938 enquiries were dealt with by letter and 11 inspections of outside properties were undertaken.

CHEMISTRY

WOOD POLYSACCHARIDES: THE HEMICELLULOSES OF BEECH

The three principal components of the cell-walls of all timbers are cellulose, lignin and hemicelluloses. The exact chemical nature of the hemicelluloses may not be sharply defined, but they may be regarded as the non-cellulosic cell-wall polysaccharides. Hydrolysis of these materials yields the individual sugar "building stones" and, in the case of wood hemicelluloses, the main sugars so produced are D-xylose, D-mannose, D-glucose, L-arabinose, D-galactose and L-rhamnose. Uronic acids are also produced. The manner in which these sugar units are linked together in the hemicellulose molecules is largely unknown.

The hemicelluloses are of great potential economic importance, for it must be remembered that they constitute almost one-third of the total carbohydrate portion of wood. Furthermore, their presence in wood pulp, paper, etc., exerts considerable influence on the properties of these products and it is clear that a fuller knowledge of the structure and inter-relationships of these polysaccharides would be extremely useful. Investigations on the hemicelluloses of beechwood have been in progress at the Laboratory for some years and it may be of interest to summarize here the knowledge that has been gained to date.

The hemicelluloses are undoubtedly mixtures of polysaccharides, and some separation of the mixture may be achieved by taking advantage of the differing solubilities and ease of extraction of the components. Thus, McDonald[28] isolated beech hemicellulose A by extracting the wood with 4 per cent sodium hydroxide. This material was studied[29] and was shown to contain residues of D-xylose and 4-0-methyl-D-glucuronic acid. The residual wood from the above extraction still contained considerable amounts of hemicellulose material not extractable with 4 per cent alkali. However, delignification of the wood with sodium chlorite followed by further alkali extractions gave hemicellulose B (with 4 per cent alkali) and hemicellulose C (with 10 per cent alkali)[30]. From preliminary investigations hemicellulose B appeared to be very similar to hemicellulose A and to another product, hemicellulose B_1, which was obtained by extraction of hemicellulose A-free wood with 17·5 per cent sodium hydroxide, without preliminary delignification[31]. These preparations, on hydrolysis, gave xylose as the only major neutral sugar. On the other hand, hemicellulose C was shown to contain appreciable amounts of glucose and mannose residues as well as xylose and uronic acid and a trace of galactose. It cannot be decided as yet whether or not this fraction is itself a mixture.

The wood remaining after removal of hemicellulose B_1 was hydrolysed and, in addition to the sugars commonly identified in such hydrolysates, the presence of very small amounts of other materials was indicated. Of particular interest was the isolation from the mixture of small amounts of a syrupy material with properties similar to fucose; this has yet to be characterized as a crystalline derivative. The wood remaining after hemicellulose C extraction gave on hydrolysis glucose with small amounts of xylose and mannose.

It has been shown elsewhere[32] that partial hydrolysis of both hardwoods and softwoods gives rise to a mixture of uronic and aldobiuronic acids, and similar results have now been obtained with beech. Paper-chromatographic evidence has indicated the presence of at least ten distinct acids in a beech hydrolysate. The complexity of this mixture has been further demonstrated by the fact that complete hydrolysis gives, as well as uronic acid components, a mixture of neutral sugars in which galactose, xylose and rhamnose predominate. Before it can be decided how these monosaccharides are linked together within the framework of the hemicellulose molecules, it will be necessary to effect a separation of the individual acids, and work is proceeding along these lines.

WOOD EXTRACTIVES: EAST AFRICAN MULBERRY (*MORUS LACTEA*)

The presence of a bright yellow, water-soluble colouring matter had been observed in the course of experimental work on the steam bending of this wood, and it was subsequently identified as morin. It had also been shown that morin is accompanied by a second, colourless, crystalline substance, which can also be extracted with water. Further work has indicated that morin is only present in the wood after it has been steamed and that the colourless substance is easily converted into morin by boiling its aqueous solution in the presence of air. It is concluded from this, and other observations, that the colourless substance is dihydromorin, i.e. 3:5:7:2′:4′–pentahydroxyflavanone, a compound that has not previously been described in the literature.

A detailed chemical examination of dihydromorin has been carried out. It has a melting point of 224°C, and the structure ascribed to it is confirmed by its ultraviolet absorption spectrum, colour reactions, and elementary analysis. Acetylation with acetic anhydride in pyridine yields the penta-acetyl derivative, m.p. 187–190°, while methylation with methyl sulphate and potassium carbonate in acetone gives 5:7:2′:4′ tetramethyl-dihydromorin, m.p. 186°, which can be further acetylated to give the 3-acetyl derivative, m.p. 166°. The structure of dihydromorin was finally confirmed by synthesis.

Several naturally occurring and synthetic dihydroflavonols are known, but the identification of dihydromorin in *Morus lactea* is of especial interest, as this is the first example of a dihydroflavonol containing a hydroxyl group in the 2′ position. Unlike other dihydroflavonols so far examined, dihydromorin cannot be prepared by reduction of the corresponding flavonol (morin), and this behaviour may perhaps be ascribed to some steric effect associated with the 2′–hydroxyl group.

DEVELOPMENT OF ACIDITY IN WOOD UNDER MOIST CONDITIONS

During the course of investigations carried out to determine the cause of corrosion of cadmium-plated components in radio receivers it was observed that certain woods, notably birch, give rise to increasing quantities of free acid during storage at high humidity and moderate temperature[33]. The acid is volatile and was found to consist almost entirely of acetic acid. In order to study further the

development of this acidity a series of samples of eight commonly used species of wood were stored at 48°C in closed vessels, each containing sufficient water to maintain the moisture content in the wood at or above fibre saturation. The storage temperature of 48°C was chosen because it was thought to be sufficiently high to prevent mould growth on the wood samples without at the same time introducing unduly accelerative effects of temperatures far above those of normal service conditions. Samples were removed at intervals and extracted with cold water, the extract then being titrated potentiometrically with standard alkali in order to determine the amount of acid present.

After seven months' storage the development of free acid was still proceeding at a rate bearing an almost linear relationship to the time of storage. The acidity of oak, the most acid species included in the experiment, had increased during this time from approximately 0·4 per cent to 3·5 per cent free acetic acid, based on the dry weight of the wood. Erratic results were obtained, however, with birch and certain other species owing, apparently, to the growth of an organism on the wood. In those samples where this contamination was observed the wood had less free acid than the original air-dry samples. Further experiments are in progress to determine, if possible, the source of acid and the mechanism of its production together with the nature of the inhibiting organisms.

WET COMBUSTION OF CELLULOSIC MATERIALS: APPLICATIONS IN ANALYSIS

It has been shown previously that digestion with a mixture of concentrated sulphuric acid and hydrogen peroxide provides a convenient and rapid method for destroying the organic matter in wood or other plant materials, and bringing the mineral components into solution in a suitable form for their determination by analytical, and particularly colorimetric, methods. Its application to the quantitative estimation of inorganic components of preservatives present in treated wood has now been studied. Most modern inorganic wood preservatives contain copper or arsenic or both as toxic constituents, and methods for the determination of these two components have therefore been examined.

Copper: 0·5 g of wood raspings is digested with sulphuric acid and hydrogen peroxide to give a clear, colourless solution, which is diluted to 100 ml. Of this solution 2 ml are extracted with a solution of zinc dibenzyldithiocarbamate in carbon tetrachloride and the coloured carbon tetrachloride solution is compared with known standards by means of a photo-electric colorimeter.

Arsenic: 2 ml of the above solution, in which the arsenic is present as arsenate owing to the oxidizing action of the hydrogen peroxide, are added to 1 per cent sulphuric acid and 0·1 per cent ammonium molybdate solution, and reduction to molybdenum blue is effected by means of hydrazine sulphate. The intensity of the blue colour is compared, after standing for one hour, with that given by standard arsenic solutions. Phosphates and silicates interfere if present in appreciable quantities.

Both the above analytical methods are highly sensitive and give reproducible results, and should be of value in the examination of preservative-treated woods.

PRODUCTION OF HARDBOARD FROM COLONIAL TIMBERS

A laboratory model Asplund Defibrator has been installed in order to study the merits of this method of preparing board-making pulps when applied to dense tropical hardwoods, and to make comparisons with the method previously described involving mild chemical cooking[34].

Preliminary trials using morabukea chips have shown that a satisfactory degree of defibration can readily be obtained during a short treatment with steam alone, involving a low power consumption. However, pulps produced in this way have very high drainage rates and are not easily refined to the extent required for production of boards having adequate strength properties, though it has been found that very small increases in drainage time produced by treatment in a disc refiner result in considerably improved strength properties. Experiments are in progress to determine, if possible, optimal conditions and power consumption in the refining stage and to compare these with values for chemically cooked pulp. Apart from strength deficiencies, an added disadvantage of the very fast-draining pulps so far produced is the difficulty experienced in producing boards of uniform colour and texture from them. The results of combining the chemical treatment and the defibration in one operation in the Defibrator have still to be examined.

Representatives of the Forest Departments of the Gold Coast, Kenya, Uganda, British Guiana, and Indonesia visiting the Laboratory during the year have shown considerable interest in the possibilities of producing hardboard from tropical timbers. A paper has been published describing the results of experimental work on African pencil cedar[35] and a general account of the hardboard work has also been published[36].

ADVISORY WORK IN CHEMISTRY

The number of external enquiries received remained at a similar level to those in previous years, the number answered by letter being 195. The occasional occurrence of salt in rock maple continues to cause concern to users of this timber, particularly in the piano-making trade, on account of the corrosive effects of the salt on metals. Information has now been received that the practice of salt seasoning is still carried on in parts of North America and it is almost certain that the salt in the wood comes from this source. Now that the origin of the salt is known it is hoped that it may be possible to arrange for salt seasoning of high grade timber intended for export to be discontinued.

PHYSICS

WOOD—WATER RELATIONSHIPS

Some interest has recently been shown, both here and elsewhere, in the quantity of water held by wood when it is completely water-logged. A block of wood in this condition contains only water and wood substance, and the volume of water should therefore be the difference between the volume of the saturated block and the volume of dry wood substance. The latter can be found from the dry weight of the block and the density of wood substance, which has approximately the same value (1·5) for all timbers. The water-holding capacity of timbers calculated in this way is a function of specific gravity, and varies from about 950 per cent moisture content with a timber of specific gravity 0·1 to about 60 per cent moisture content with a timber of specific gravity 1.

In order to compare calculated with observed values, specimens of seventeen timbers, ranging from quipo (specific gravity 0·12) to ekki (specific gravity 1·06) were first evacuated, then flooded with water to cover them completely and finally subjected while still immersed to normal atmospheric pressure, after which the moisture contents were determined. The highest moisture content was 850 per cent, with quipo, and the lowest 30 per cent, with wallaba. For some purposes it is better to consider, not the actual moisture content, but its ratio to the calcu-

lated maximum. Expressed in this way, the majority of timbers took up between 90 and 100 per cent of the maximum, but in the denser timbers the absorption tends to be less than this. The lowest values, however, were obtained with gaboon, a medium density timber, which took up only 29 per cent of the maximum. A low absorption (55 per cent of the maximum) was also shown by wallaba, but this timber, in addition to having a high density, also has a high resin content, which probably affects the water absorption.

It is often assumed that as the moisture content of wood is decreased from complete saturation, the relative humidity remains at 100 per cent until a particular moisture content (the fibre saturation point) is reached, after which the relative humidity drops steadily with decreasing moisture content.

It was shown some years ago at the Laboratory that by improving the accuracy of vapour pressure measurements, measurable deficits from saturation vapour pressure were observed at moisture contents much higher than those usually accepted. More recent work carried out elsewhere on other materials, particularly soils, has shown that by observing the moisture content variation when a suction is applied to the material, it is possible to derive the relation between vapour pressure and moisture content at deficits from saturation far smaller than those directly observable in vapour pressure experiments. Preliminary tests showed that the technique used for soils was not suitable for wood, but a method has been devised whereby the moisture content–suction curve can be measured over a limited range of suctions. Results are so far available only for Sitka spruce. The specimens used had a saturation moisture content of about 250 per cent and application of a suction of 140 cm water reduced the moisture content to about 230 per cent. The specimens were taken through desorption and adsorption cycles between 10 cm and 140 cm suction, and showed considerable hysteresis. On the results so far available, it appears that there is a deficit from saturation vapour pressure at very high moisture contents, although the deficit is too small to be detected by a direct measurement of vapour pressure.

Following observations made in the course of work on timber mechanics, experiments have been carried out on the equilibrium moisture content of gaboon plywoods containing different numbers of plies in the same aggregate thickness. Small samples of the plywoods containing 3, 7, 11, 15 and 19 plies were dried to vacuum over phosphorus pentoxide to constant weight. They were then exposed in vacuum to a saturated solution of manganese chloride corresponding to a relative humidity of 51 per cent until the weights were again constant. Samples of gaboon veneer both untreated and treated with the same hardener as used in the plywood were likewise exposed. The equilibrium moisture contents ranged progressively from 8·9 per cent for the untreated veneer to 11·9 per cent for the 19-ply plywood. The veneer treated with the hardener also showed a small but significant rise in moisture content.

The rise in moisture content may be due to the hardener introducing salts into the wood, and the observed results therefore direct attention towards the effect of salts on the hygroscopicity of wood. This question is, however, of wide interest, especially in connexion with the effect of sodium chloride treatment and impregnation of wood by sea water. Although a certain amount of information on this subject is available, it is fragmentary and a series of experiments has been planned to study the question further.

The first experiment of the series, using laboratory reagent sodium chloride, has been completed. The sodium chloride content of the wood corresponded with the amount which would be introduced by saturation with sea water, and the

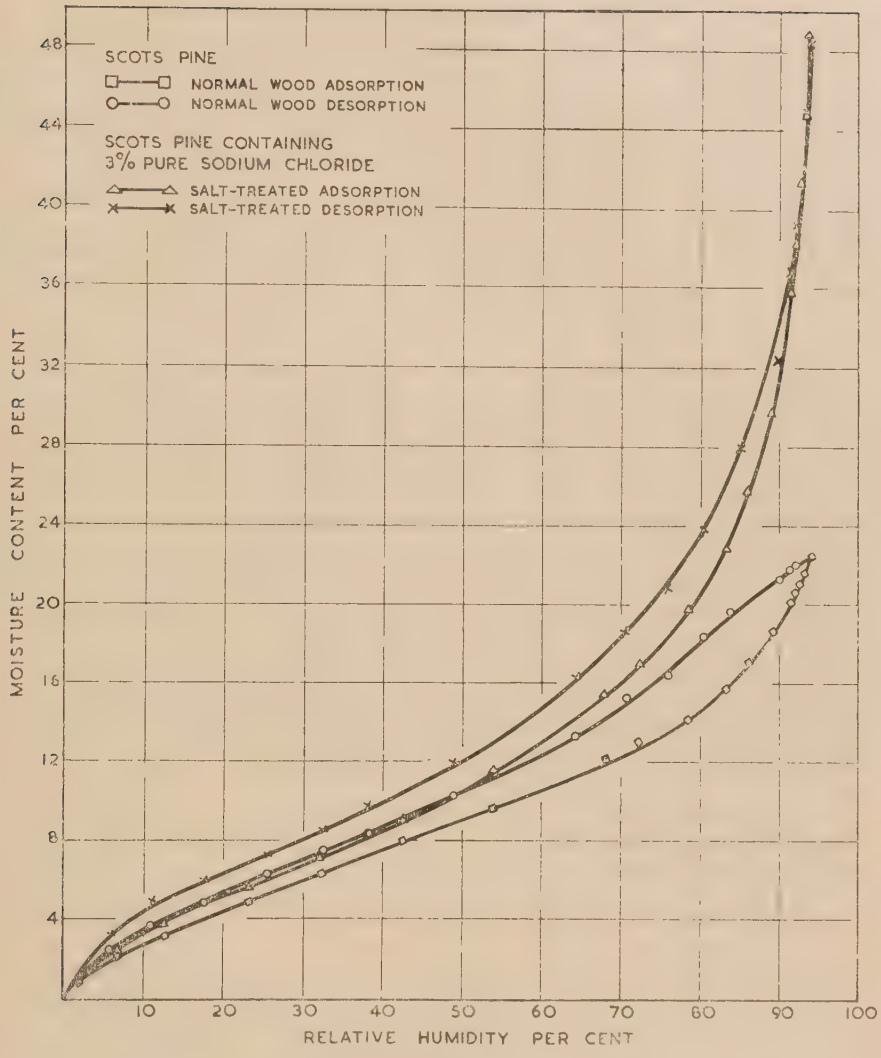


Fig. 7. Isothermals for untreated and salt-treated Scots pine

results are shown in comparison with those for normal wood in Fig. 7. At all relative humidities, the equilibrium moisture content of the salt-treated wood is higher than that of the untreated wood, and at humidities above about 60 per cent the excess moisture content increases rapidly. The relative humidity over a saturated sodium chloride solution is 75 per cent, and above this humidity a rapid increase in the equilibrium moisture content of treated wood is to be expected owing to dilution of the sodium chloride. The excess moisture contents observed at lower humidities are unexpected and, so far, unexplained, but it is hoped that further work now in progress may throw light on them.

For this work, a simplified version of the present apparatus has been designed and made. With two sets of apparatus, between them capable of carrying out simultaneously fourteen experiments, it is intended to study the effect of species, salts and other factors on the hygroscopicity of wood.

VIBRATION METHODS

In connexion with non-destructive methods of testing wood, work has continued on the effect of shear on the frequencies of bending vibration of wooden beams. The frequencies depend mainly on the dimensions of the beam and on the modulus of elasticity in the length direction but they are also affected by the occurrence of shear deformations in the plane of vibration of the beam.

Two beams of beech as closely matched as possible were cut having cross-sectional dimensions 2×1 in. In one specimen, the tangential direction in the wood lay parallel to the larger cross-sectional dimension, and in the other specimen it lay parallel to the smaller dimension. The frequencies of vibration of each beam were measured first with the plane of vibration parallel to the larger dimension, and then with the plane parallel to the smaller dimension. Owing to the way in which the specimens were cut, the shear effect in the first beam when vibrating parallel to its larger cross-sectional dimension should depend on the same shear modulus as the effect in the second beam when vibrating parallel to its smaller cross-sectional dimension. Analysis of the results shows that this is so, and the agreement between the observed and calculated frequencies is very close; a similar series of measurements on ash is almost complete and confirms the results on beech. Wood has considerable advantages for a test such as this, because it is possibly the only material which can be obtained in large enough sizes, and which at the same time has different shear moduli in the two principal planes of the cross-section.

The agreement obtained between the experimental and theoretical results enables corrections to be applied so that a true modulus of elasticity can be calculated from the frequency of vibration and dimensions of the beam. The first step is the calculation of the uncorrected modulus (E_0) from the simple theory in

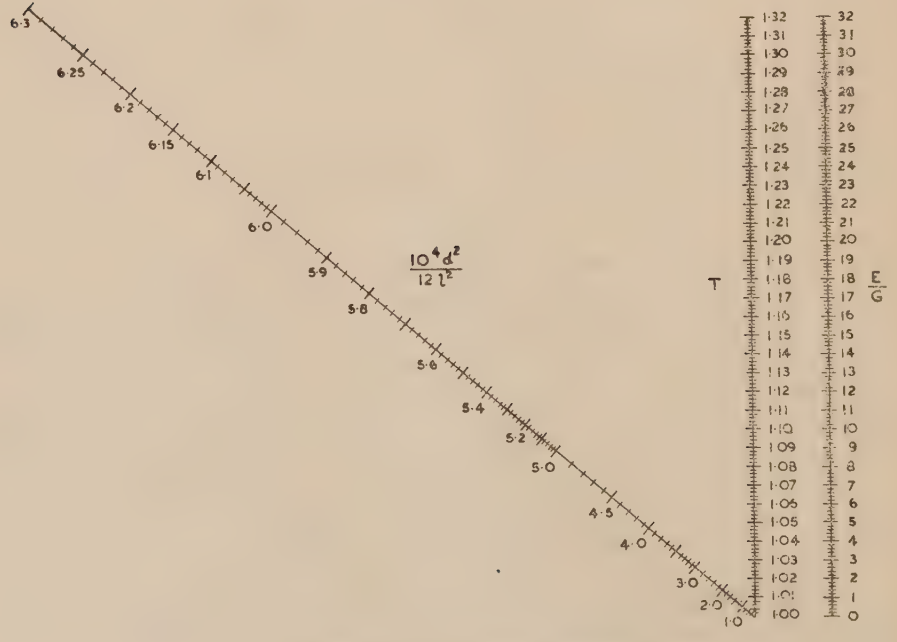


Fig. 8. Nomogram for correcting vibration results

which shear effects are ignored. The true modulus is then given by $E=E_0T$, where T is a factor which allows for the effect of shear, and which depends mainly on the ratio of depth (d) to length (l) of the beam, and on the ratio of elasticity modulus (E) to shear modulus (G). The calculation of T is a somewhat lengthy process, and to facilitate the calculations, tables have been constructed giving T as a function of d/l and E/G for the first three modes of vibration. In the case of the first (fundamental) mode of vibration, a nomogram has also been constructed (Fig. 8) which enables T to be found by laying a straight edge between the appropriate values of $10^4d^2/12l^2$ and E/G, and reading off the value of T on the middle scale.

FREQUENCY OF VIBRATION AND ELASTIC STABILITY

Work carried out some years ago in America stressed the connexion between frequency of lateral vibration of a system under load and its elastic stability. It was suggested that there should be an approximately linear relationship between the applied load and the square of the ratio of the frequencies of the stressed and the unstressed system, and that the frequency ratio should become zero at a load equal to the critical buckling load. The practical interest of these suggestions lies in their possible application to proof testing and to the determination of critical loads of complicated systems not really subject to theoretical analysis. However, the suggestions do not seem to have been tried out on any simple, well defined system for which the critical load can be calculated theoretically. One such system is a strut clamped at one end and free at the other, subjected to an end compression. During the past year measurements have been carried out and analysed on strips of wood, brass and steel, in which the frequency of lateral vibration was measured at a number of applied loads. On plotting the square of the frequency ratio against load, straight lines were obtained, and by extrapolation, the load corresponding with zero frequency was determined. These loads were then compared with those calculated from the Euler formula for critical load. The agreement was very close, showing that, at least for this system, it would be possible to estimate the critical load from frequency measurements.

MISCELLANEOUS AND ADVISORY WORK IN PHYSICS

Some progress has been made with the construction of an apparatus for producing atmospheres of known relative humidity. This will be used in examining the behaviour of humidity-measuring devices.

External and internal enquiries have dealt, among other matters, with vibration properties, thermal conductivity, dielectric properties, detection of metal in wood, heat retention by wood and concrete, structural analysis of cabinet furniture, and statistical treatment of experimental results.

EXTERNAL RELATIONS

A total of 9557 cu. ft of timber was brought into the Laboratory, i.e. 258 cu. ft more than during the preceding year. Of this quantity, 8685 cu. ft was for testing and 872 cu. ft for service trials in the cable drum industry. The amount of both home-grown and imported hardwoods increased considerably. The imported timber comprised 3383 cu. ft of hardwood and 400 cu. ft of softwood, and the home-grown 2255 cu. ft of hardwood and 3519 cu. ft softwood.

The following is a detailed list of timber procured :

Name	*Source*	*Quantity (cu. ft)*	*Section Testing*
Imported hardwoods			
Keruing	Borneo Forest Service	274	General test
Yellow seraya	„	311	„
Tasmanian myrtle	Commercial	15	Bending
Ricinodendron rautanenii	„	13	Chemistry
Ramin	„	338	Seasoning
Maracaibo boxwood	„	5	Mycology and Seasoning
White seraya	Borneo Forest Service	340	General test
Greenheart	Commercial	27	Bending
Iroko	„	27	„
East African olive	Sudan Government	427	General test
Light red seraya	Borneo Forest Service	362	„
White bombway	Commercial	250	Seasoning
Japanese oak	„	150	„
French beech	„	590	„
Chrysophyllum albidum	Uganda Forest Service	128	Composite Wood
Bosquiea phoberos	„	111	„
Imported Softwoods			
Swedish redwood	Commercial	400	Seasoning
Home-grown hardwoods			
Nothofagus obliqua	Forestry Commission	21	Seasoning, Bending, Timber Mechanics
Beech	„	1224	General work
Oak	„	382	„
Sweet chestnut	„	20	Wood Preservation
Sycamore	„	45	Woodworking
Turkey oak	„	36	Entomology
Ash	„ and Private Estates	526	Timber Mechanics, Bending, Woodworking
Home-grown softwoods			
Leyland cypress	Forestry Commission	70	General test
Scots pine	„	1135	„
Sitka spruce	„	500	Service tests
„	„	238	General test
Japanese larch	„	175	„
„	„	372	Service tests
Douglas fir	„	1029	General tests
Sitka spruce	„	128 discs	External Relations

GENERAL TESTING

During the year five reports on the following imported timbers under test were completed :

Yellow pine (*Pinus strobus*), Nicaraguan pitch pine, Andaman bulletwood, African padauk and muhuhu.

On three additonal hardwoods, two species of light red seraya and kapur, the work has been completed and reports are being prepared. Six other tropical hardwoods are in various stages of test : yellow, white and red seraya, keruing, pillarwood and East African olive. These tests will be completed during the coming year.

TIMBER QUALITY IN RELATION TO SILVICULTURE

The work in co-operation with the Forestry Commision on the quality of timber in relation to the site and soil has continued.

During the year, nine consignments were procured, five of which were for full-scale tests. They included two parcels of Scots pine, one from the New Forest and the other from Strathspey, Scotland; western hemlock from Novar Estate, Scotland, and two consignments of Douglas fir, one from Gareloch Forest, Scotland, and the other from the Forest of Dean. In addition, two lots of five trees each were procured: one of Japanese larch from Cumberland which was over fifty years old and the other of Sitka spruce from Parc Stalwyn, North Wales, which had been underthinned and slower-grown than the material obtained for the standard tests. The latter consignment will also give an interesting comparison with a former one obtained from Gwydyr Forest, which is within ten miles of Parc Stalwyn.

A large mature tree of Leyland cypress (*Cupressocyparis leylandii*) measuring 70 cu. ft was brought in. This species is a hybrid of Monterey cypress (*Cupressus macrocarpa*) and yellow cypress (*Chamaecyparis nootkatensis*). The work was undertaken at the request of the Forestry Commission, as they are interested in this hybrid.

An investigation was made into the quality of the timber of Sitka spruce from trees grown from seed collected from different sources. Four parcels of five trees each were obtained from sample plots in the Radnor Forest, the origin of the seed being the Queen Charlotte Islands, Washington, Oregon and California. The work has been carried out and the report completed. The findings indicate that timber produced from the seed collected in the Queen Charlotte Islands is superior in density and strength to that of the other three. The results will need confirmation as the trees were small, being only thirty years old.

From observations made during the Sitka spruce provenance tests, it was decided to investigate more closely the question of rate of growth in relation to specific gravity. One hundred and twenty-eight discs were obtained from Kerry Forest for this project and the work is now in progress.

During the year reports were published on one consignment of lodgepole pine, two of *Abies grandis* and on the Leyland cypress. A composite report was compiled on the six consignments of Sitka spruce already tested.

Work on two consignments of Scots pine has been completed and the reports are with the printers.

REVISION OF EMPIRE AND HOME-GROWN TIMBERS HANDBOOKS

The work on the *Handbook of Hardwoods* was completed during the year and the book was published in March, 1956. The *Handbook of Softwoods* has been completed and is in the press.

SERVICE TESTS ON HOME-GROWN CONIFERS FOR CABLE DRUMS

The Laboratory's work of sawing and grading the timbers for this test was completed during the year. Sitka spruce and Japanese larch were converted and despatched to the cable drum makers. It will be about two years before the first results of these service tests are known.

WINDBLOWN TIMBER

Some of the logs resulting from the gale damage in Scotland in 1953 have been stored in water for over two years pending their utilization. A visit was paid to the windblown area to inspect these logs and report upon their condition in the water and on conversion[37].

TRADE SURVEYS

This work was resumed last year and is continuing. The surveys on the use of timber in the manufacture and repair of railway rolling stock and the use of timber in the musical instruments industry have been completed and the reports have been written[38,39]. Both surveys produced much interesting information as to the methods and the timbers used in these industries.

During the year two more surveys were begun, one on the use of timber in sports goods and the other on that in road vehicles. The field work on the first is completed, and the report is being written. The survey of timbers in road vehicles is likely to take some time owing to the size of the industry and the variety of vehicles being made.

VISITS

In addition to the large number of visits by officers of specialist sections on specific industrial problems, general contact with firms was maintained at about the same level as that of the preceding year. Altogether sixty-seven firms were visited, for liaison or to gain data for surveys.

VISITORS AND EDUCATION

There has been a further increase in the time given to visitors to the Laboratory, mainly owing to a large number of overseas visitors. The timber trade and timber-using firms sent 170 representatives on general educational visits, a slight increase on last year, while the visitors it was possible to accept from Associations, Technical Colleges and Government Departments totalled 240, about the same number as last year.

During the Congress at Oxford of the International Union of Forest Research Organizations, thirty delegates paid a visit to the Laboratory and were given demonstrations of the work in progress. The opportunity was also taken of convening a meeting at the Laboratory of entomological delegates from several countries for a discussion on current forest and timber insect problems.

A party of thirty members of Colonial Public Works Departments paid a visit to the Laboratory and were shown the work being carried on, especially that on tropical timbers.

Two official Government delegations visited the Laboratory, one from the Union of Soviet Socialist Republics, and the other from Roumania. Both parties were shown the organization of the Laboratory and the work in hand was explained to them.

Visitors from overseas numbered 145, nearly double that of the preceding year; they represented forty-one countries—Australia, Austria, Belgium, British Guiana, Burma, Canada, Denmark, Fiji, Finland, France, Germany, the Gold Coast, Holland, India, Indonesia, Italy, Jamaica, Japan, Kenya, Malaya, Mauritius, Nigeria, North Borneo, Pakistan, the Philippines, the Federation of Rhodesia and Nyasaland, Roumania, Sarawak, South Africa, Spain, Sudan, Sweden, Switzerland, Tanganyika, Thailand, Trinidad, Turkey, Uganda, the United States, the U.S.S.R., Yugoslavia.

These overseas visitors represented a variety of trades; most of them were timber merchants, foresters and engineers. One party consisted of twenty-five French timber merchants and architects who were making a tour of the timber yards and certain woodworking industries of this country.

The Utilization Officers from the three East African Colonies all visited the Laboratory and spent several days in the various sections discussing problems on timbers from their respective districts.

A larger number of persons requiring long courses were accommodated during the year. These students came from British Guiana, Burma, Denmark, India, Italy, Switzerland and Thailand, several of them being members of the staffs of established or projected forest products research laboratories in their own countries.

The students of the four University Forestry Schools came for the customary courses of instruction; the total number was seventy-two. Engineering students numbering twenty from the Imperial College were given a day's instruction.

Six courses have been held in kiln seasoning, attended by forty-one students, and three students have received special training in wood bending.

LECTURES AND EXHIBITIONS

The demand for lectures by specialist members of staff to technical audiences is still great and has been met as far as it has been possible to do so.

The requests for participation in exhibitions fluctuate from year to year. This year an exhibit was displayed at the Building Exhibition, Olympia, where there was a special section devoted to the utilization of timber. In addition to a number of specimen planks of hardwood species of interest to the British user, there was a comprehensive explanatory range of softwoods to exemplify the softwood grading rules recently recommended by the Laboratory.

For the National Boat Show, assistance was given to Lloyds Register of Shipping by the preparation of an exhibit to illustrate the effects of electrochemical action on boat timbers, and the means whereby they can be avoided. Exhibits were also prepared and demonstrated at the Conference and Exhibition on Electro-heating in Industry and Commerce, held at Cardiff.

ADVISORY AND LIAISON WORK IN EXTERNAL RELATIONS

The number of technical enquiries dealt with by letter was 303, an increase of 49 on last year's number.

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F. Y. Henderson,
Director

Forest Products Research Laboratory,
Princes Risborough,
Aylesbury, Bucks.

January, 1957.

APPENDIX I

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY

31st *December*, 1956

Director of Forest Products Research: F. Y. Henderson, C.B.E., D.Sc., D.I.C.

ADMINISTRATION

Assistant Director: J. Bryan, M.Eng., A.M.I.C.E.
Senior Principal Scientific Officer: P. Harris, B.Sc.(Eng.), A.M.I.Mech.E.
Higher Executive Officer: R. D. Weeks, M.B.E.
Executive Officer: Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge); E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Senior Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officer: G. L. Franklin.
Assistant Experimental Officer: D. G. Patterson, B.Sc.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, F.Inst.P. (Officer in Charge).
Experimental Officers: E. H. Adams; J. Mc.C. Paton.
Temporary Assistant Experimental Officer: J. Perkins.

SECTION OF SEASONING

Principal Scientific Officer: W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers: R. E. Hodge, Assoc.I.Mech.E.; D. D. Johnston; G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Assistant Experimental Officer: R. H. Wynands.

SECTION OF TIMBER MECHANICS

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: J. G. Sunley, M.Sc.
Scientific Officer: A. J. Comben, B.Sc.
Senior Experimental Officer: A. J. Foord.
Experimental Officers: G. R. Brock; W. T. Curry.
Assistant Experimental Officers: S. A. Covington; Miss W. M. Fogerty; W. T. Hide.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer: D. N. R. Smith (Officer in Charge).
Experimental Officers: R. Cockcroft; Miss E. Lee; D. F. Purslow, B.Sc.; L. W. Redding.

SECTION OF CHEMISTRY

Principal Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Senior Scientific Officer: R. A. Laidlaw, B.Sc., Ph.D.
Senior Experimental Officer: D. F. Packman, B.E.M.
Experimental Officer: L. C. Pinion, B.Sc.
Temporary Assistant Experimental Officer: G. A. Smith.

SECTION OF MYCOLOGY

Senior Principal Scientific Officer: W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C., A.I.C.T.A. (Officer in Charge)
Principal Scientific Officer: J. G. Savory, B.Sc.
Experimental Officer: E. C. Badcock.
Assistant Experimental Officer: Miss C. A. Clements, B.Sc.

SECTION OF ENTOMOLOGY

Principal Scientific Officers: R. C. Fisher, B.Sc., Ph.D., F.R.S.E. (Officer in Charge). J. D. Bletchly, B.A., B.Sc., F.R.E.S.
Scientific Officer: M. G. White, M.A., F.R.E.S.
Senior Experimental Officer: E. C. Harris, F.R.E.S.
Experimental Officer: Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: K. J. S. Walker, M.A.
Senior Experimental Officers: H. J. Endersby; R. Goodchild.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer: F. G. O. Pearson, B.Sc. (Officer in Charge).
Senior Experimental Officer: A. V. Thomas, M.Eng.
Experimental Officer: Miss C. Webster.
Assistant Experimental Officer: Miss H. A. Fielding, B.A.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: J. F. S. Carruthers, B.Sc., A.M.I.Mech.E.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Experimental Officer: R. W. Hudson.
Temporary Experimental Officer: B. H. Paxton.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer: C. J. N. McCracken, B.A., Dip.For. (Officer in Charge).
Temporary Assistant Experimental Officer: J. A. H. Broughton, B.Sc.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer: W. J. Baldwin.
Experimental Officer: E. A. Steel, A.M.I.Mech.E.

APPENDIX II

LIST OF PUBLICATIONS ISSUED DURING 1956

A. Stationery Office Publications

Forest Products Research, 1955.

Handbook of Hardwoods.

Bulletins:

No. 36 Meranti, Seraya and Allied Timbers. By J. D. Brazier, B.Sc.
No. 37 Working Stresses of Structural Softwoods. By J. G. Sunley, M.Sc.
No. 38 Efficiency of Adhesives for Wood. By R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E.

Leaflets:*

No. 9 The Moisture Content of Timber in Use. (*Revised Edition.*)
No. 18 A Cross-shaft Overhead Fan Kiln. (*Revised Edition.*)
No. 37 Selecting Ash by Inspection. (*Revised Edition.*)
No. 40 The Prepartion of Wood for Microscopic Examination. (*Revised Edition.*)
No. 41 Wood Waste as a Fuel. (*Revised Edition.*)
No. 42 Kiln-drying Schedules. (*Revised Edition.*)
No. 43 Spray Treatment for Prevention of *Lyctus* Attack in Sawn Logs. (*Revised Edition.*)
No. 50 Defects Caused by Ambrosia (Pinhole Borer) Beetles. (*Supersedes No.* 17.)
No. 51 Reaction Wood. (Tension Wood and Compression Wood.)

Special Report:

No. 11 The Blunting of Wood-cutting Edges. By H. J. Endersby.

B. Other Publications

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APPENDIX III

REFERENCE LIST OF COMMON NAMES CITED IN TEXT

African mahogany = *Khaya* spp.
African padauk = *Pterocarpus soyauxii*
African pencil cedar = *Juniperus procera*
Afrormosia = *Afrormosia elata*
American oak = *Quercus* spp.
American pitch pine = *Pinus palustris* and allied spp.
Andaman bow-wood = *Sageraea elliptica*
Andaman bulletwood = *Mimusops littoralis*
Ash = *Fraxinus excelsior*

Baltic redwood = *Pinus sylvestris*
Baltic whitewood = *Picea abies*
Beech = *Fagus sylvatica*
Beech, French = *Fagus sylvatica*
Birch = *Betula* spp.
Bow-wood, Andaman = *Sageraea elliptica*
Boxwood, Maracaibo = *Gossypiospermum praecox*
Bulletwood, Andaman = *Mimusops littoralis*

Caribbean pitch pine = *Pinus caribaea*
Cedar, Western red = *Thuja plicata*
Ceiba = *Ceiba* spp.
Chai = *Sageraea elliptica*
Chestnut, Sweet = *Castanea sativa*
Corsican pine = *Pinus nigra* var. *calabrica*
Cypress, Leyland = *Cupressocyparis leylandii*

Douglas fir = *Pseudotsuga taxifolia*

East African mulberry = *Morus lactea*
East African olive = *Olea hochstetteri*
Ekki = *Lophira alata*
Elm = *Ulmus* spp.
English oak = *Quercus robur* and *Q. petraea*
European larch = *Larix decidua*
European oak = *Quercus robur* and *Q. petraea*
European plane = *Platanus acerifolia*
European redwood = *Pinus sylvestris*

Fir, Douglas = *Pseudotsuga taxifolia*
Fir, Silver = *Abies alba*
French beech = *Fagus sylvatica*

Gaboon = *Aucoumea klaineana*
Greenheart = *Ocotea rodiaei*

Hemlock, Western = *Tsuga heterophylla*

Iroko = *Chlorophora excelsa*

Japanese larch = *Larix leptolepis*
Japanese oak = *Quercus* spp.

Kapur = *Dryobalanops lanceolata*
Keruing = *Dipterocarpus* spp.

Larch = *Larix* spp.
Larch, European = *Larix decidua*
Larch Japanese = *Larix leptolepis*
Leyland cypress = *Cupressocyparis leylandii*
Light red seraya = *Shorea* spp.
Lodgepole pine = *Pinus contorta* var. *latifolia*

Mahogany, African = *Khaya* spp.
Mangrove = *Rhizophora* spp.
Maple = *Acer* spp.
Maple, Rock = *Acer saccharum* (principally)
Maracaibo boxwood = *Gossypiospermum praecox*
Meranti = *Shorea* spp.
Mfunda = *Cynometra webberi*
Morabukea = *Mora gonggrijpii*
Muhuhu = *Brachylaena hutchinsii*
Mulberry, East African = *Morus lactea*
Mutenye = *Guibourtia arnoldiana*
Myrtle, Tasmanian = *Nothofagus cunninghamii*

Nicaraguan pitch pine = *Pinus caribaea*

Oak = *Quercus* spp.
Oak, American = *Quercus* spp.
Oak, English = *Quercus robur* and *Q. petraea*
Oak, European = *Quercus robur* and *Q. petraea*
Oak, Japanese = *Quercus* spp.
Oak, Persian = *Quercus castaneaefolia*
Oak, Turkey = *Quercus cerris*
Obeche = *Triplochiton scleroxylon*
Ocote pine = *Pinus oocarpa*
Olive, East African = *Olea hochstetteri*

Padauk, African = *Pterocarpus soyauxii*
Pencil cedar, African = *Juniperus procera*
Persian oak = *Quercus castaneaefolia*
Pillarwood = *Cassipourea malosana* (syn. *C. elliottii*)
Pine = *Pinus* spp.
Pine, American pitch = *Pinus palustris* and allied spp.
Pine, Caribbean pitch = *Pinus caribaea*

Pine, Corsican = *Pinus nigra* var. *calabrica*
Pine, Lodgepole = *Pinus contorta* var. *latifolia*
Pine, Nicaraguan pitch = *Pinus caribaea*
Pine, Ocote = *Pinus oocarpa*
Pine, Scots = *Pinus sylvestris*
Pine, Southern = *Pinus palustris* and allied spp.
Pine, Yellow = *Pinus strobus*
Plane, European = *Platanus acerifolia*

Quipo = *Cavanillesia platanifolia*

Ramin = *Gonystylus* spp.
Redwood = *Pinus sylvestris*
Redwood, Baltic = *Pinus sylvestris*
Redwood, European = *Pinus sylvestris*
Redwood, Swedish = *Pinus sylvestris*
Roble = *Nothofagus obliqua*
Rock maple = *Acer saccharum* (principally)

Sequoia = *Sequoia sempervirens*
Seraya = *Parashorea* and *Shorea* spp.
Scots pine = *Pinus sylvestris*
Seraya, Light red = *Shorea* spp.
Seraya, White = *Parashorea plicata*
Seraya, Yellow = *Shorea* spp.
Silver fir = *Abies alba*
Sitka spruce = *Picea sitchensis*
Southern pine = *Pinus palustris* and allied spp.
Spruce = *Picea* spp.
Spruce, Sitka = *Picea sitchensis*
Swedish redwood = *Pinus sylvestris*
Sweet chestnut = *Castanea sativa*
Sycamore = *Acer pseudoplatanus*

Tasmanian myrtle = *Nothofagus cunninghamii*
Thingan = *Hopea odorata*
Turkey oak = *Quercus cerris*

Wallaba = *Eperua falcata* and *E. grandiflora*
Walnut = *Juglans* spp.
Western hemlock = *Tsuga heterophylla*
Western red cedar = *Thuja plicata*
White bombway = *Terminalia procera*
White seraya = *Parashorea plicata*
Whitewood, Baltic = *Picea abies*

Yellow pine = *Pinus strobus*
Yellow seraya = *Shorea* spp

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